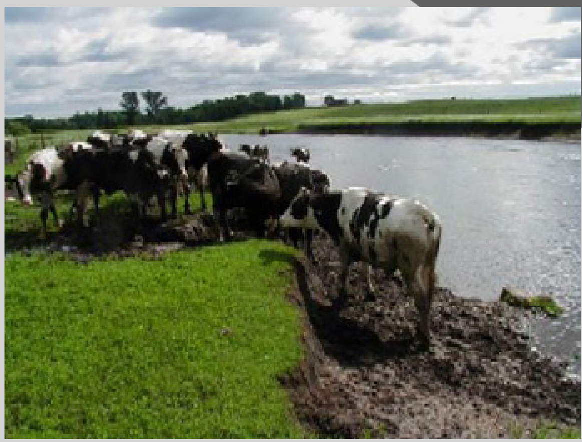
BIOLOŠKE VODOGRADNJE
P7

EKOLOŠKO UREĐENJE
I OBNOVA VODOTOKA

Zaključna razmatranja

What did we do

- Introduction
- Lake Restoration
- **Stream Restoration**
- Wetland Restoration



Wide range of projects called "Stream Restoration"

Small-scale bank stabilization or revegetation

Arlington, VA Dept. of Environmental Resources

Complete channel realignment or redesign

stream & habitat scales

- at what scale do we want to restore:

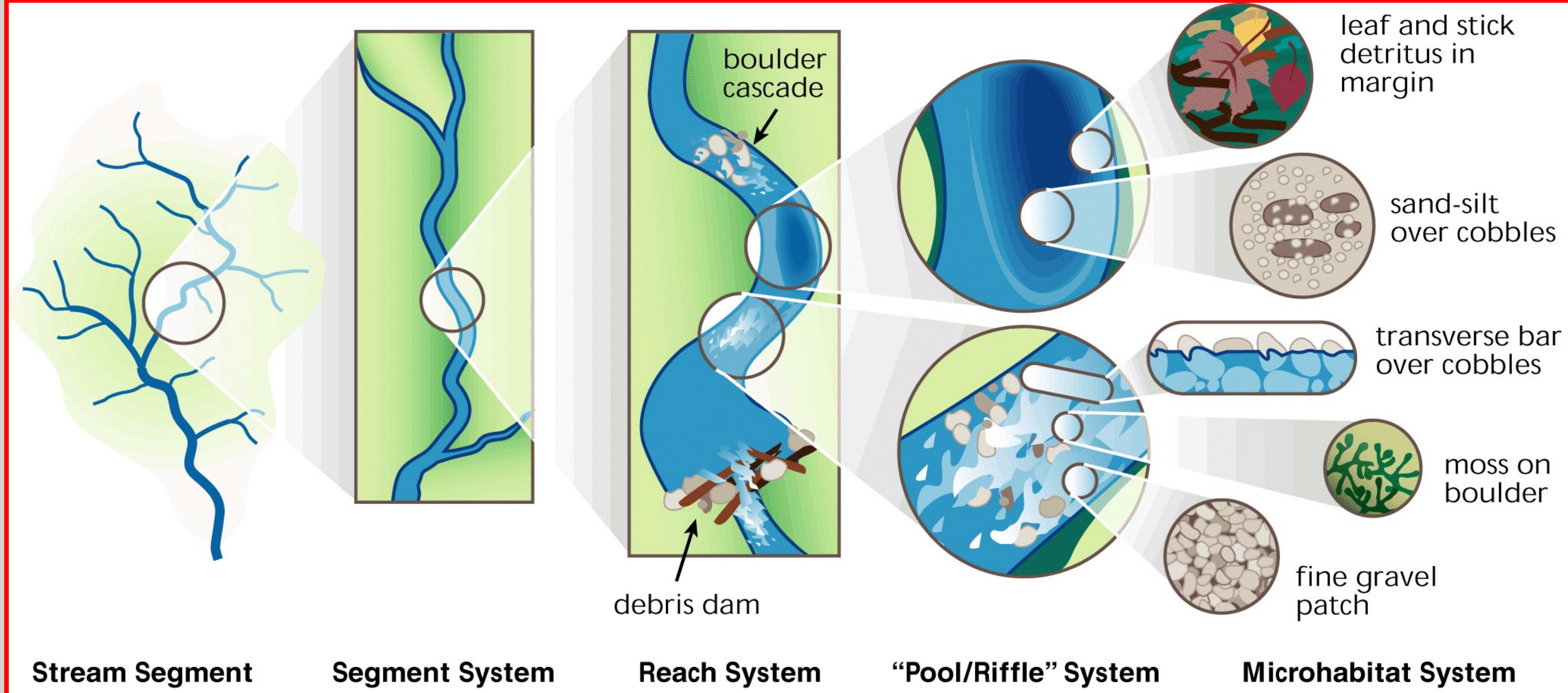


Fig. 2.32 -- Hierarchical organization of a stream system and its habitat subsystems.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).

"Stream Restoration" is not well defined but there are several consistent elements

- A desire for a more "natural looking" channel
- Integrate ecology & geomorphology with engineering
- Work with natural processes (self-sustaining design)

Restoration is the return of the *form* and *function* of an ecosystem to some pre-disturbance condition.

Summary of Basics:

-Restoration begins with identifying the morphological characteristics of the “reference stream reach” (ie, reference conditions for stream restoration). Width, depth, flow, bankfull discharge, bottom materials, riffles and pool habitats.

-Riparian habitat is often a secondary consideration, but is ecologically critical.

Restoration philosophy

“Process of returning a river or watershed to a condition that relaxes human constraints on the development of natural patterns of diversity.

Restoration philosophy

Restoration does not create a single, stable state, but enables the system to express a range of conditions dictated by the biological and physical characteristics of the watershed and its natural disturbance regime”

(Frissell and Ralph 1998)

Stream restoration considerations

In addition to in-stream habitat, current restoration projects should consider:

- Geomorphology at a watershed scale
- Inclusion of physical scientists (interdisciplinary)
- Fluvial geomorphology, sediment transport, channel hydraulics, hydrology
- Historical information to document the evolution of the channel
- How processes have been altered by human activities in the watershed
- Water Quantity Issues

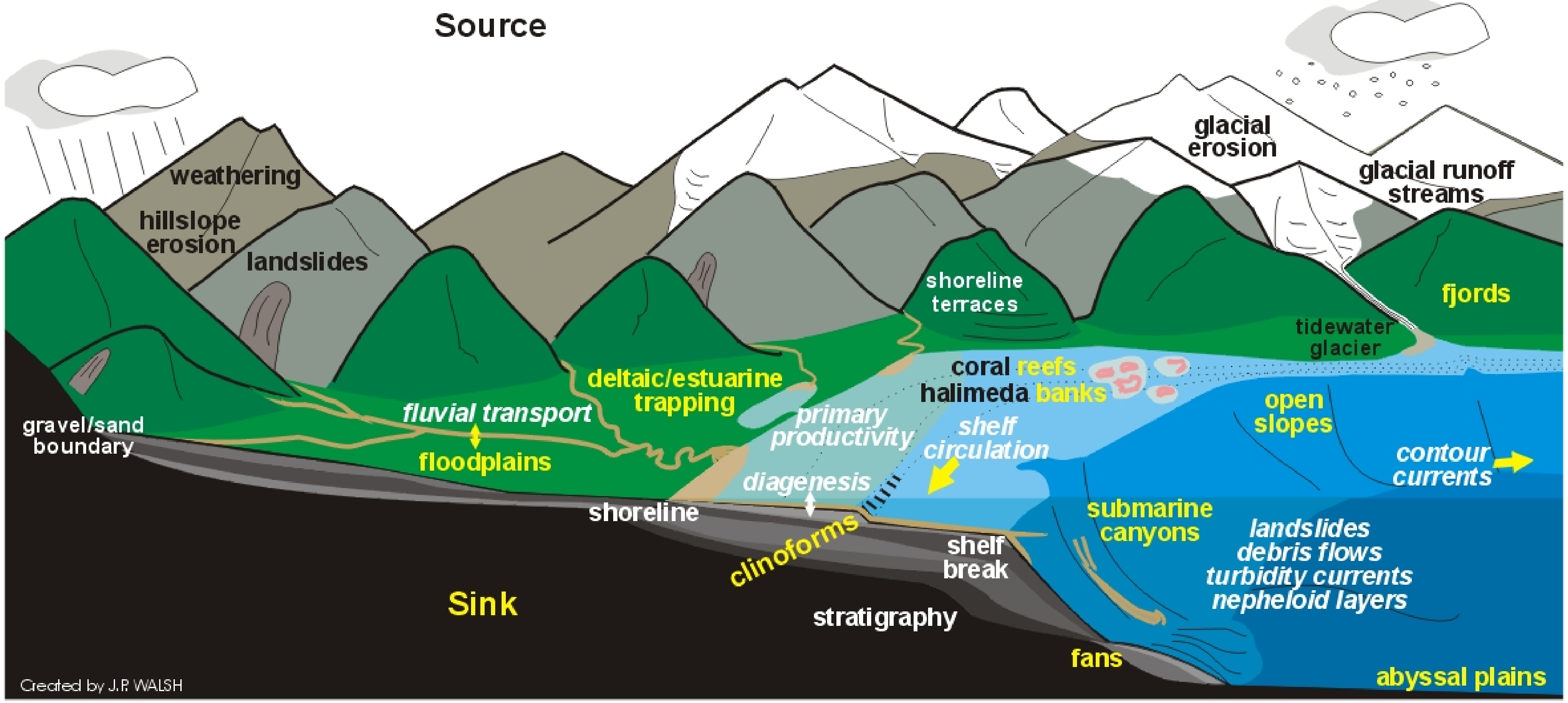
Common major considerations

- Habitat:
  - Water temperature
  - Topographic complexity
  - Desirable ranges of U, h
- Channel stability – ability to convey high flows without major changes in form
- Pollutant reduction (e.g. susp. sediment)
- Nutrient processing – especially N, P
- Esthetics & recreation

Stream channel stability

- "Morphologically defined as the ability of the stream to maintain, over time, its dimension, pattern, and profile in such a manner that it is neither aggrading nor degrading and is able to transport without adverse consequences the flows and detritus of its watershed" (Rosgen 1996)

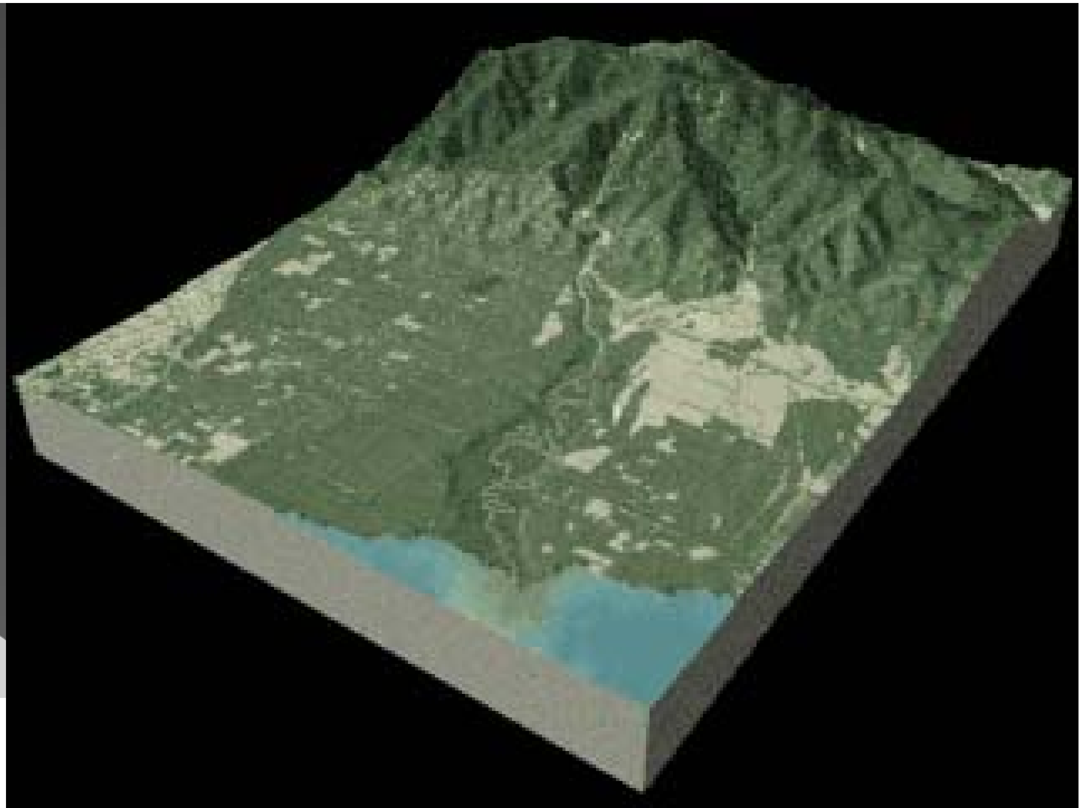
river systems

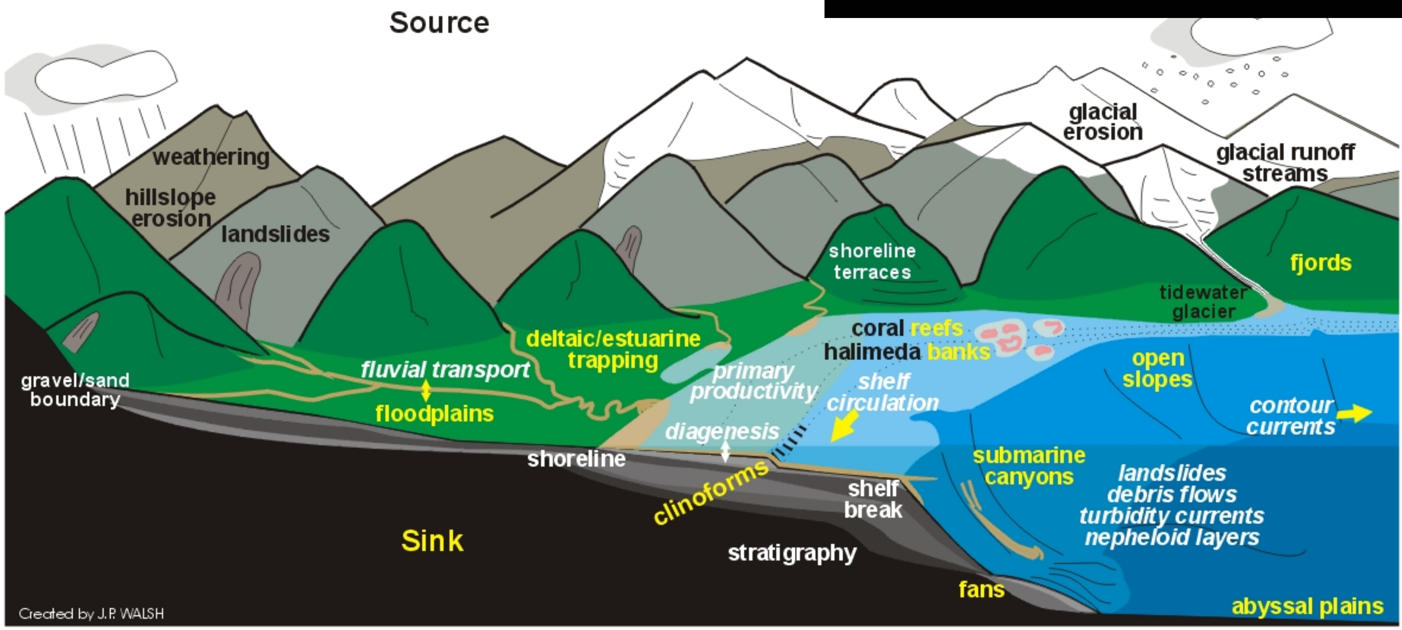


river systems

can be subdivided into major segments:

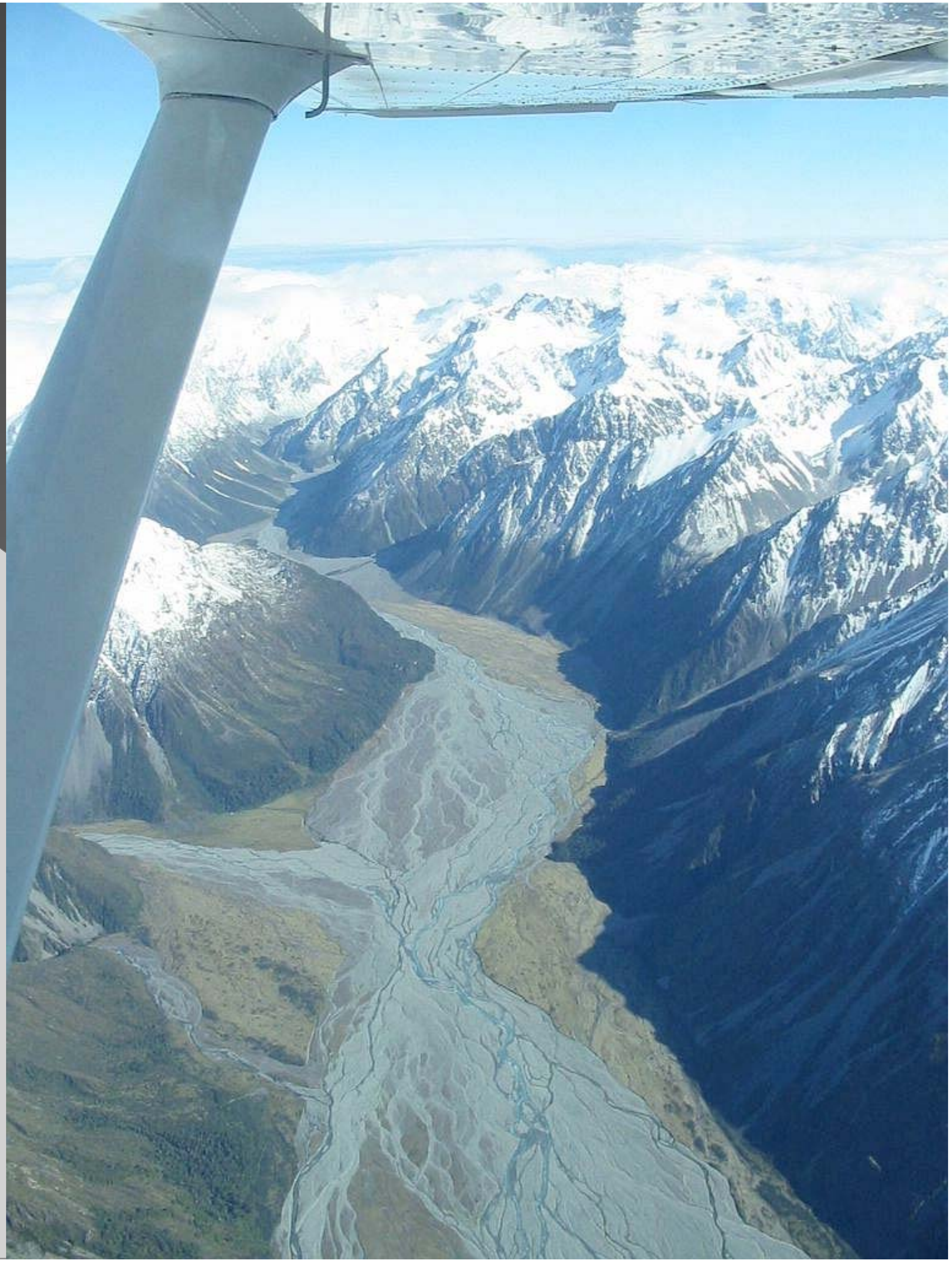
1. bedrock/mountain
2. **alluvial**
3. deltaic





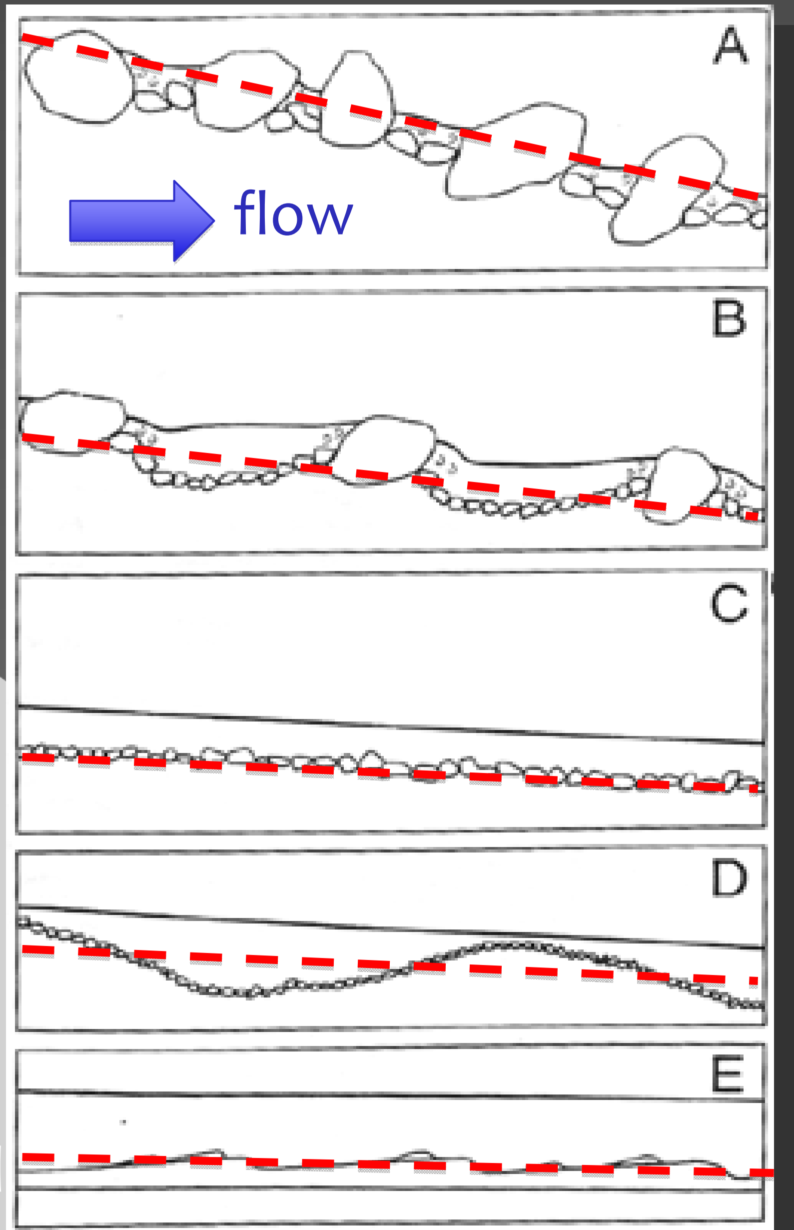
Alluvial Rivers

- erodible channel boundaries (alluvial banks and bed)
- transport capacity ≤ sediment supply
- **Input ≥ Output**
- *sed. storage can be big*
- channel forms/patterns reflect self-organization to deal with this…



Channel Types

- Colluvial (sediment from hillslope)
- Alluvial (fluvial sediment)
  - A. Cascade
  - B. Step-pool
  - C. Plane-bed
  - D. Pool & riffle (most common)
  - E. Dune – ripple
  - **ordered by decreasing gradient**
  - ***and* degree to which everyd flow can carry sediments**



[Montgomery & Buffington 1997]

Channel Types

Colluvial Channels

Small headwater channels at the tips of the channel network where sediment transport is dominated by landslide processes.

Channel Types

- **Alluvial (fluvial sediment)**

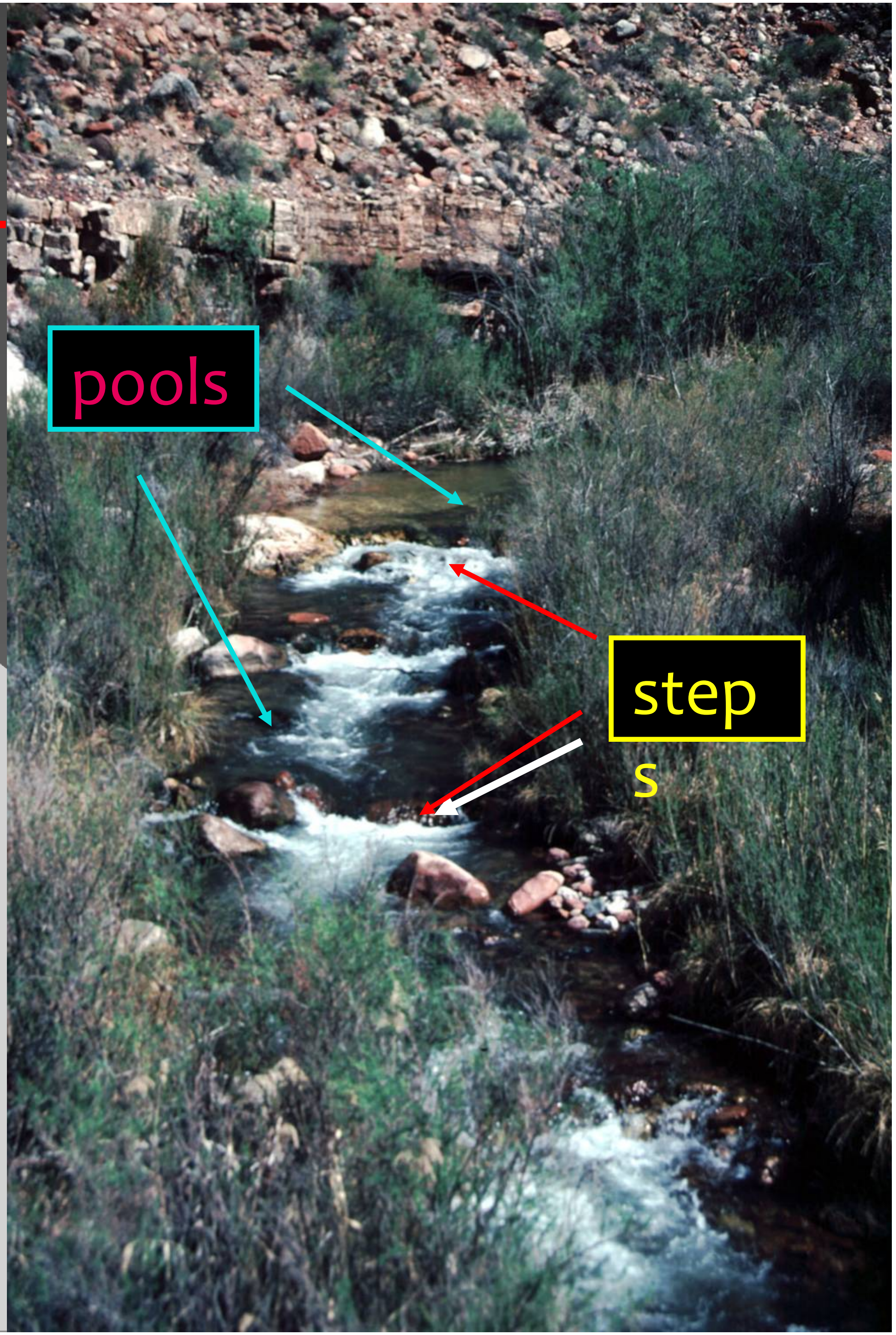
Cascade Channels

The steepest of mountain channels, characterized by tumbling flow around individual boulders; *disorganized* streambed structure.

Channel Types

Step-Pool Channels

Channels displaying *full-width-spanning* accumulations of coarse sediment that forms a sequence of steps.



Channel Types

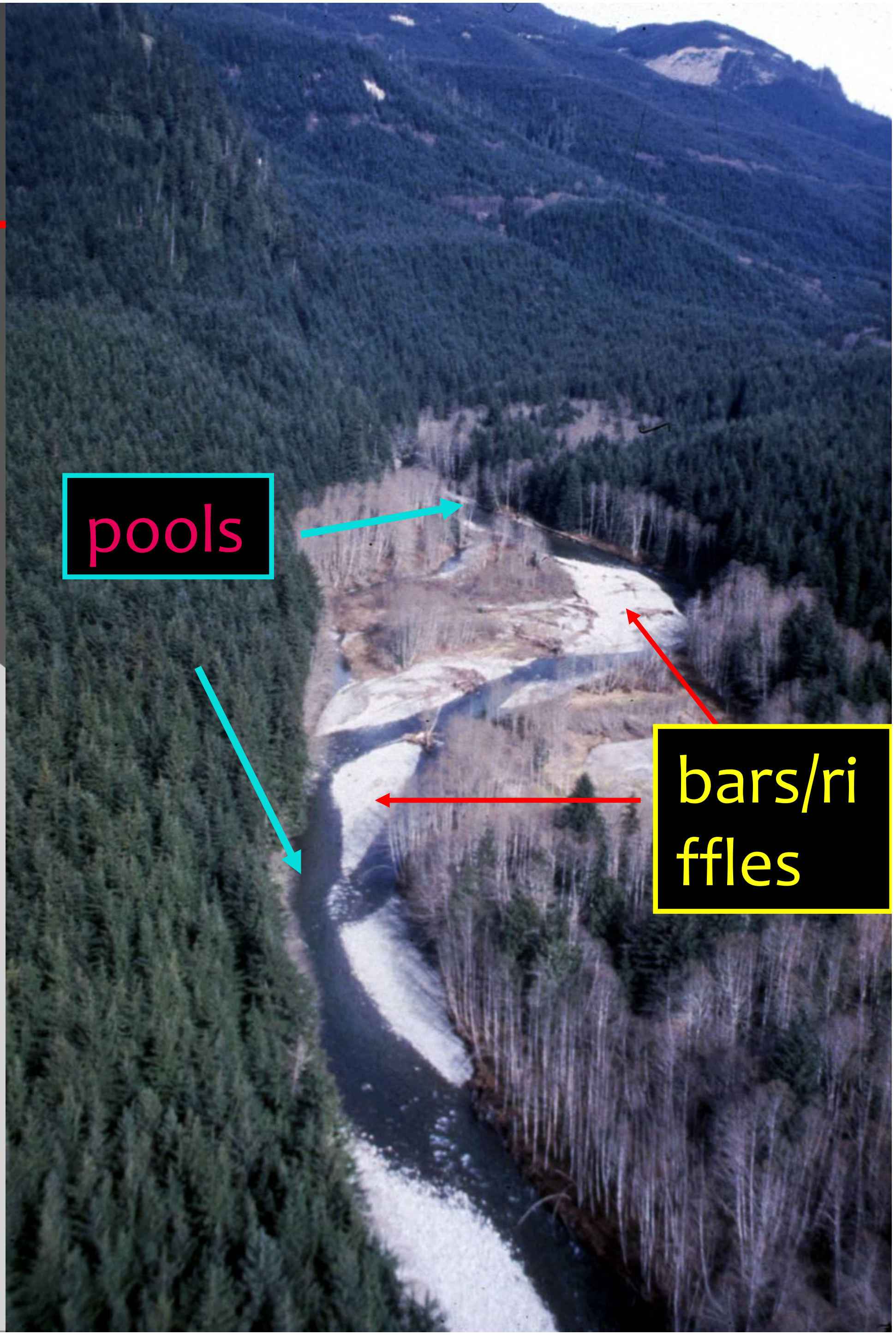
Plane-Bed Channels

Channels lacking well-defined bedforms and instead displaying long reaches lacking pools.

Channel Types

Pool-Riffle Channels

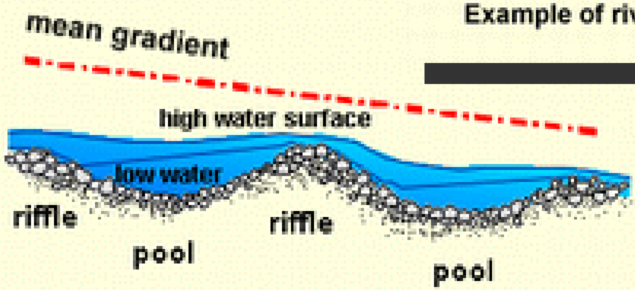
The most common mountain river morphology; characterized by alternating sequence of pools and bars.

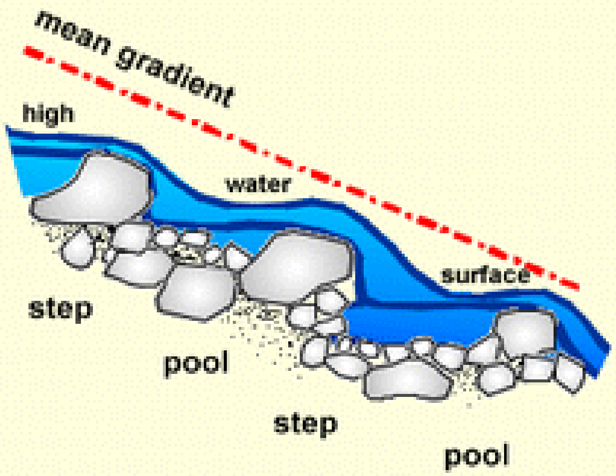


Riffles, Pools, and Cascades

- Riffles and pools alternate in somewhat predictable patterns
- Associated with optimal flow organization to move sediment

Example of river channel morphology (top view)





Riffle and Pool Habitat

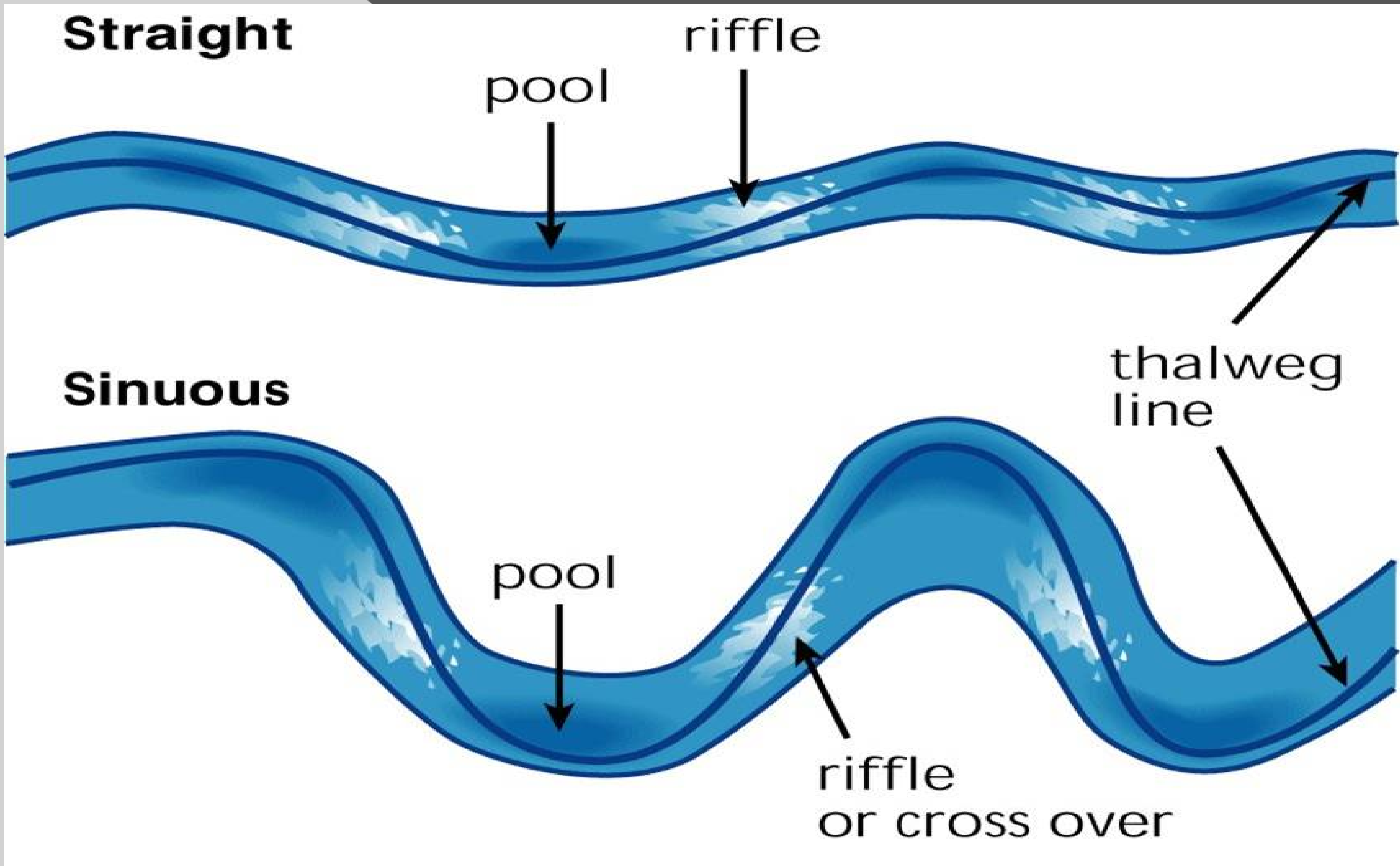
-**Riffles** are rocky shallow areas with fast moving water. Water churns, high oxygen content. Biologically very active areas.

-**Pools** are deeper water areas. Slower moving water.

-Most streams are characterized by a never ending sequence of riffles and pools.

Pool - Riffle Sequence

- Riffle to riffle = 5 - 7 channel widths



Runs- are similar to riffles in that the water is fast moving and shallow. Different in that, generally, stones are not above the water. This allows for more light penetration.

Larger streams have riffles, pools and runs.

Dimension: (cross section)

- Width/depth ratio at bankfull stage
- Entrenchment ratio
  - Width of flood prone area/bankfull width
- Dominant channel materials
  - sizes or types

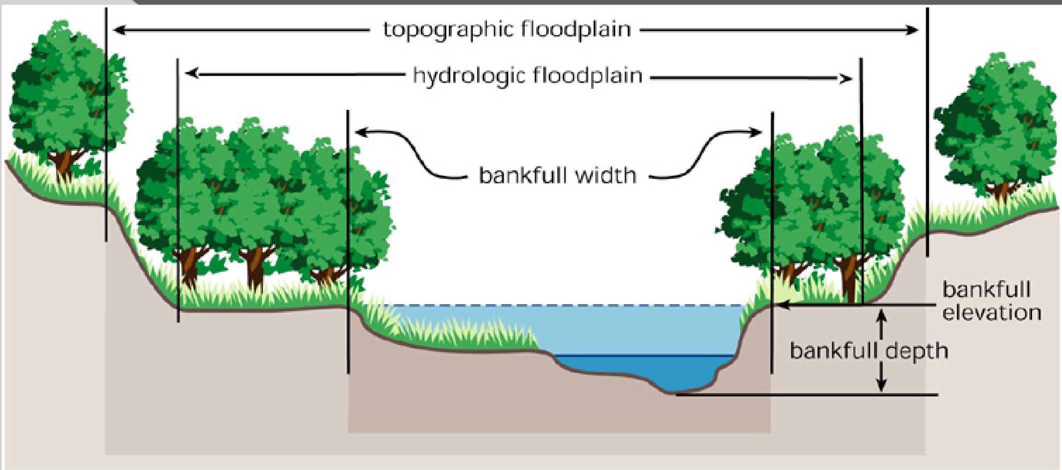


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

fluvial sub-environments

- river environments we might consider:

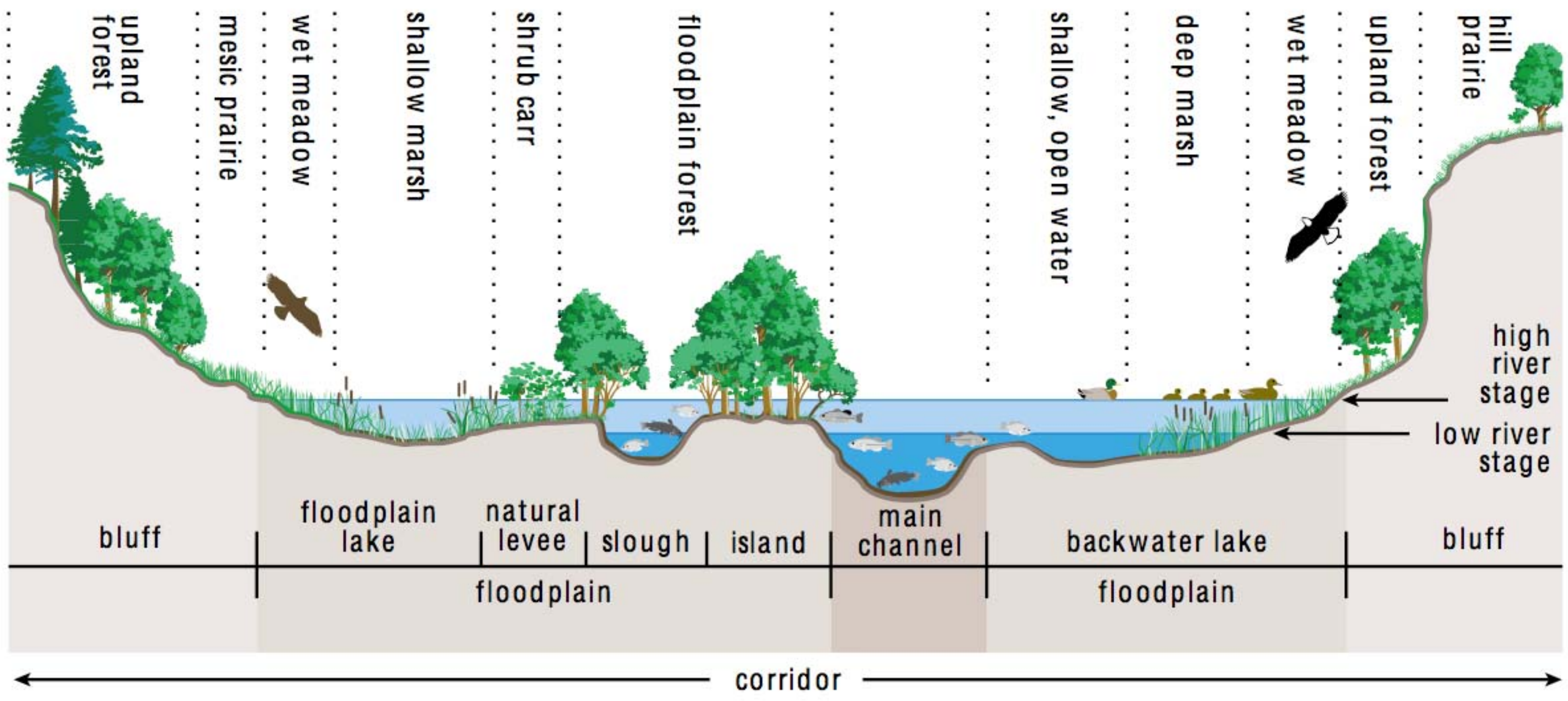
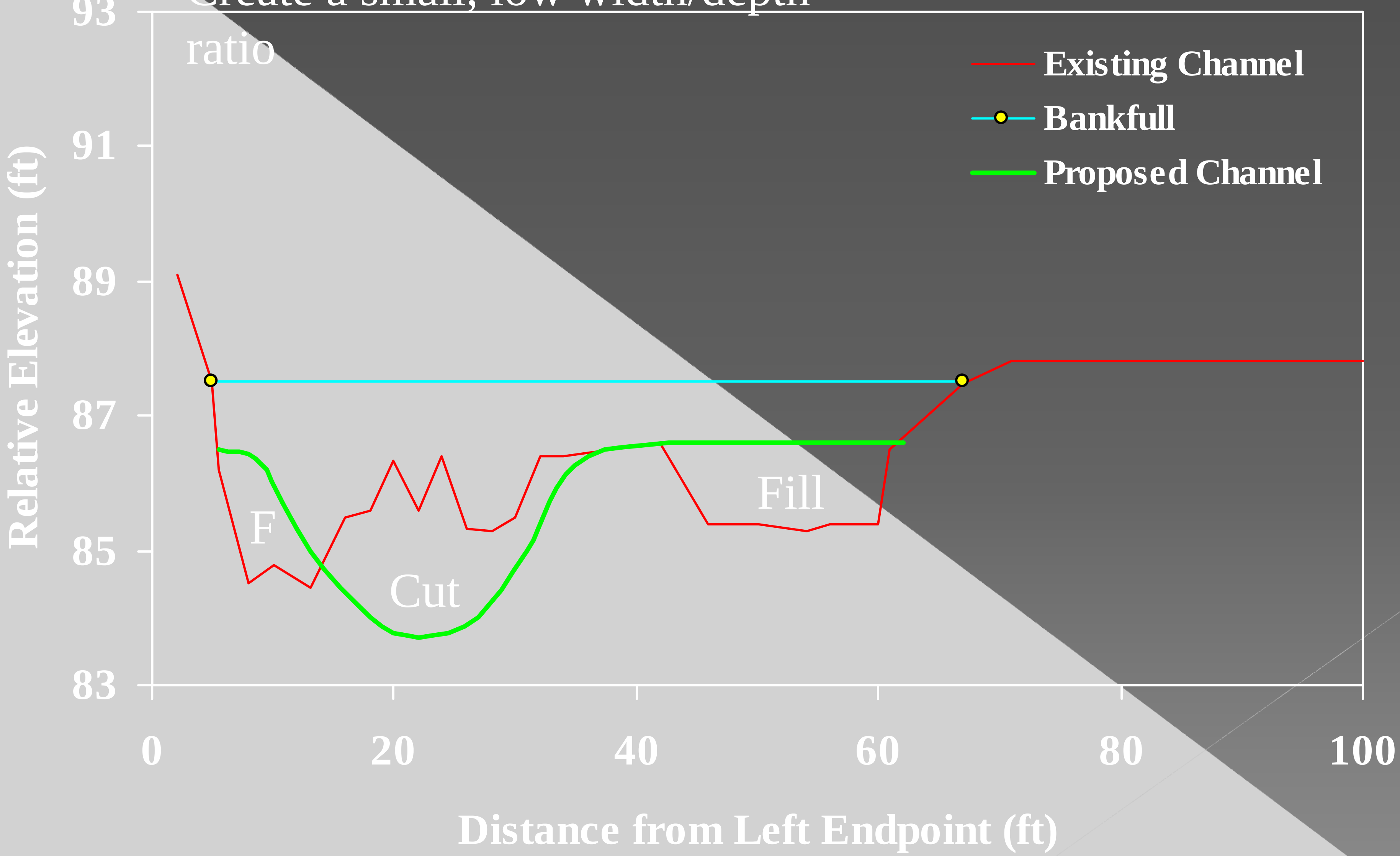


Figure 1.11: A cross section of a river corridor. *The three main components of the river corridor can be subdivided by structural features and plant communities. (Vertical scale and channel width are greatly exaggerated.)*

Restoration Design – Typical Cross Section

Create a small, low width/depth ratio



Channel Construction

Cross Vanes

Provide grade control, reduce bank erosion, and maintain deep pools downstream of each structure.

Duration

Duration:

Ephemeral: Rarely full, usually only during the rainy season. Sometimes these streams are called "flashy." Often found in upland forests. Dry, stony channels.

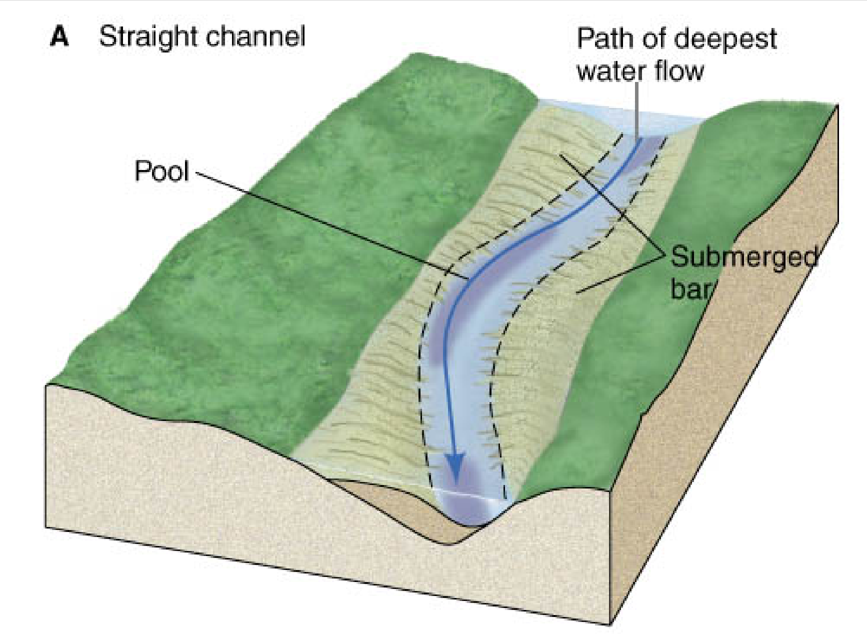
Intermittent- Full of water during part of the year. Usually full in spring early summer, drying out in later summer and early fall during hot dry conditions.

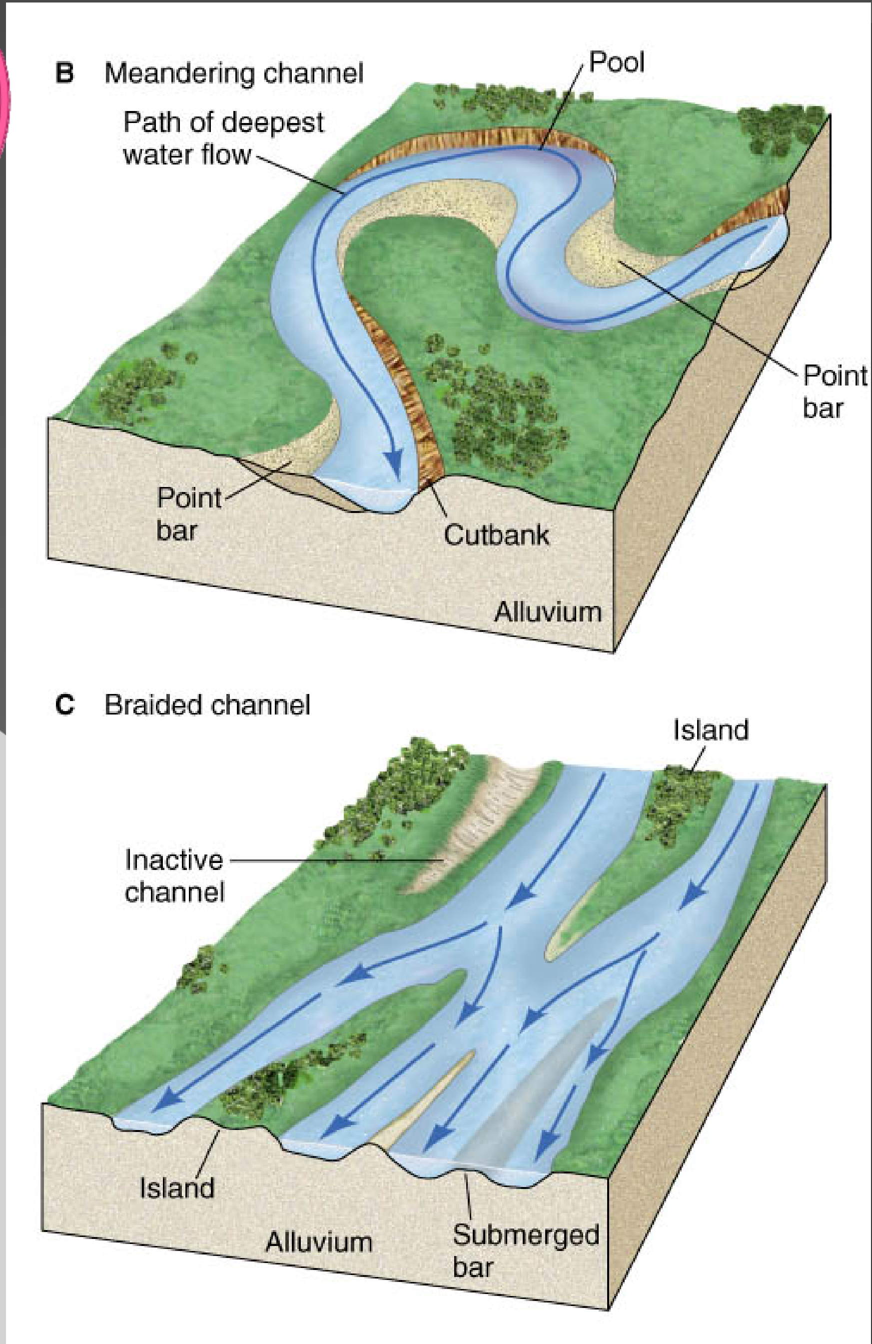
Perennial Stream- Full year round, assumed to never dry out.

Pattern (plan view)

Three basic map-pattern forms of streams:

- Straight
- **Meandering**
- Braided



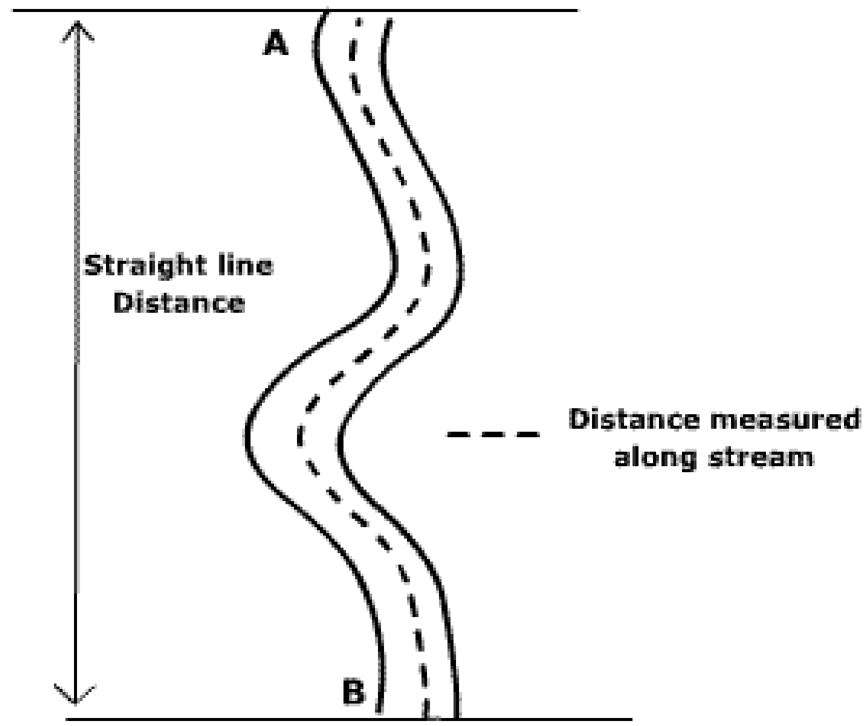


Pattern (plan view)

- Sinuosity
  - **stream length/valley length**
- Meander width ratio (secondary measurement)
  - **meander belt width/bankfull width**

Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

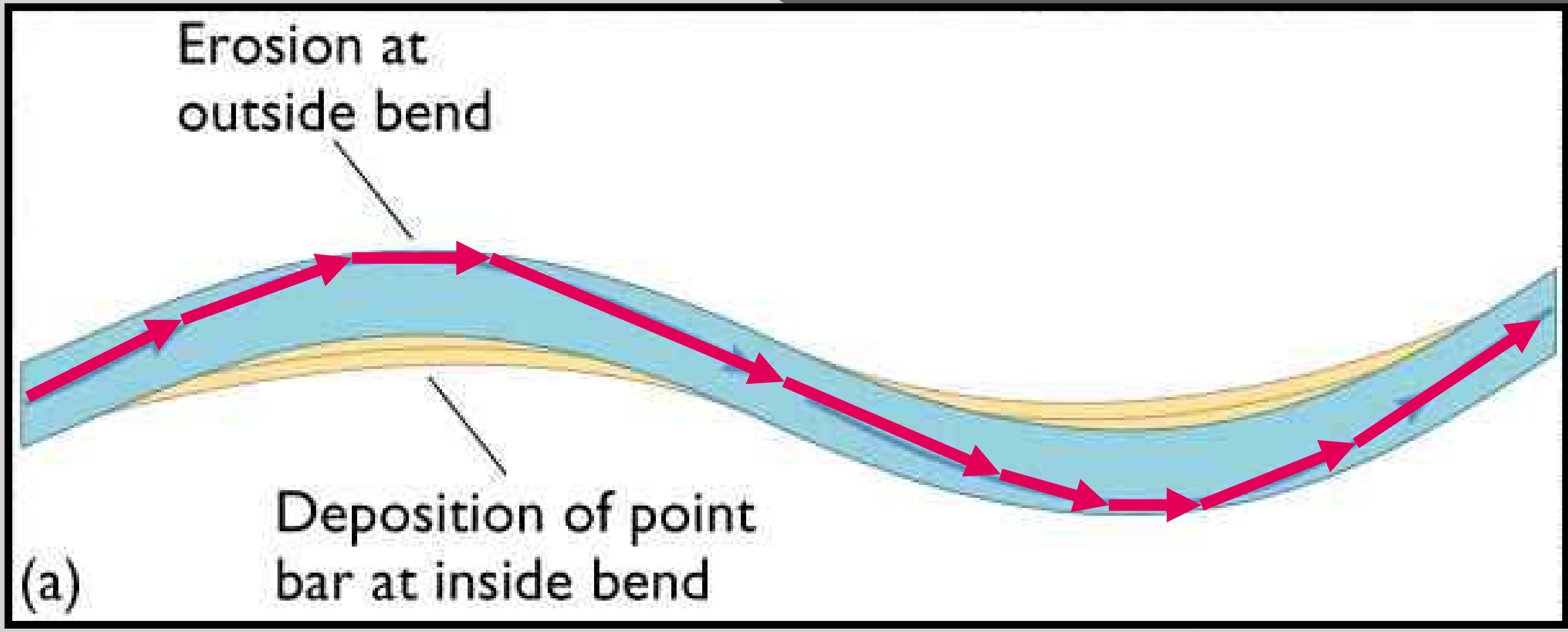
Sinuosity



$$\text{Sinuosity ratio} = \frac{\text{Distance measured between two points along stream}}{\text{Straight line distance between two points}}$$

Meandering

- What if the banks are erodible?
  - higher velocity near bars → erosion
  - erosion → deposition …
- Flow & sedimentation patterns self-reinforcing



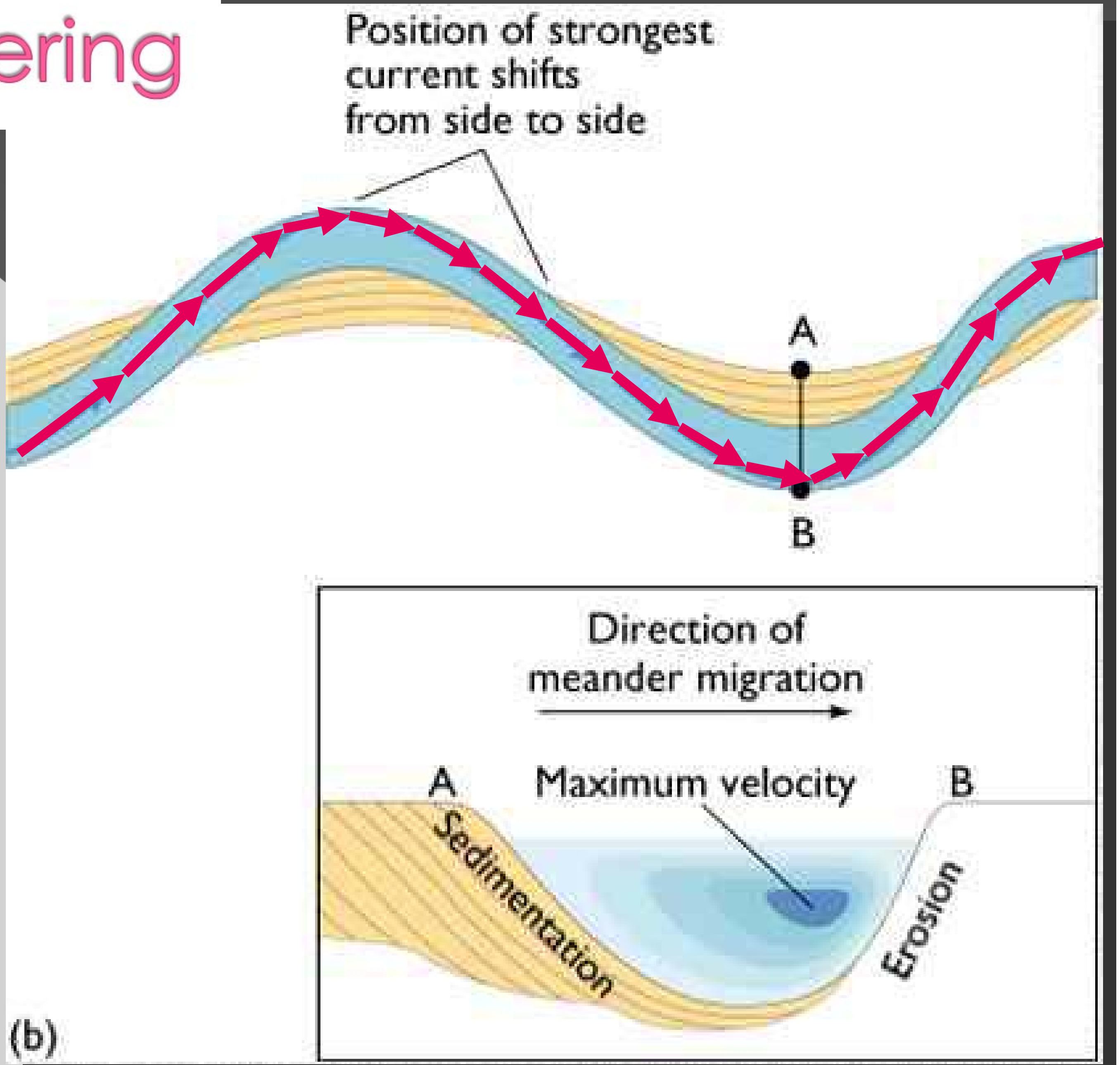
Meandering

Meandering leads to formation of:

- cut banks
- point bars

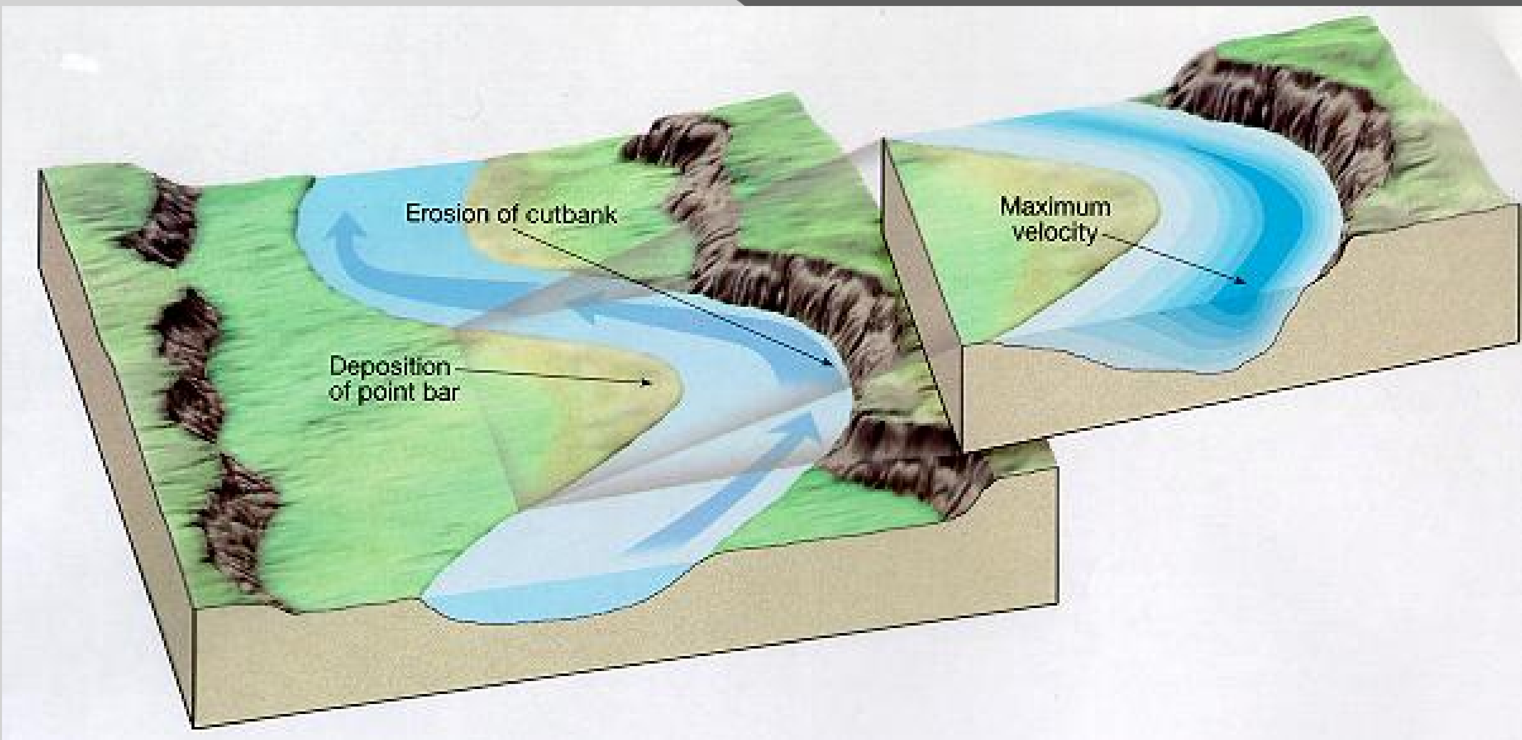
Note velocity patterns:

- highest on outside of bends



Meandering

- Erosion on outside of bends (cut banks) where velocity is greatest
- Deposition on the inner sides of bends where velocity is slower
- Meanders grow through time…

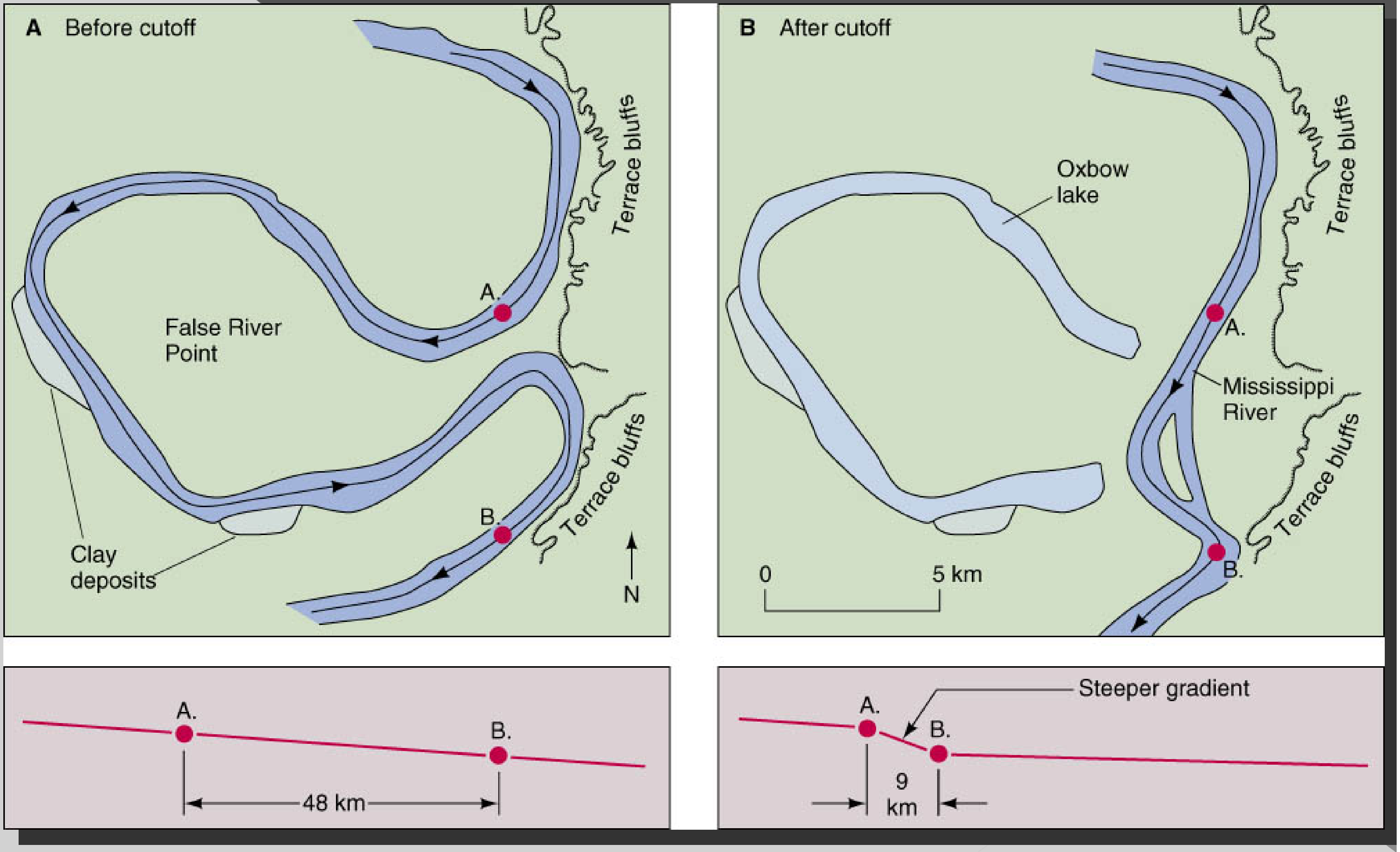


Meandering

Cut Banks

Point Bars

Growing meanders can intersect each other and cut off a meander loop, forming an **oxbow lake**

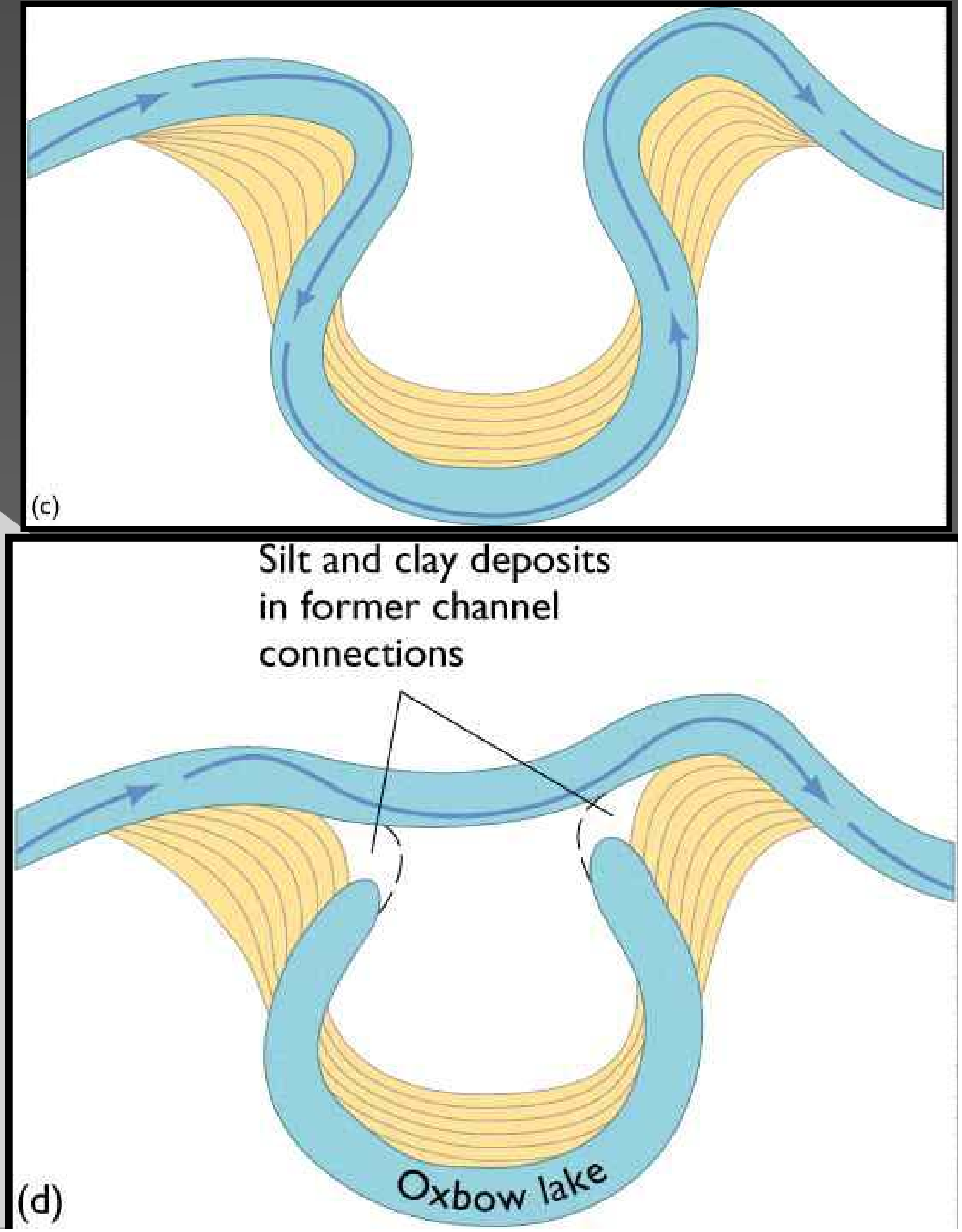


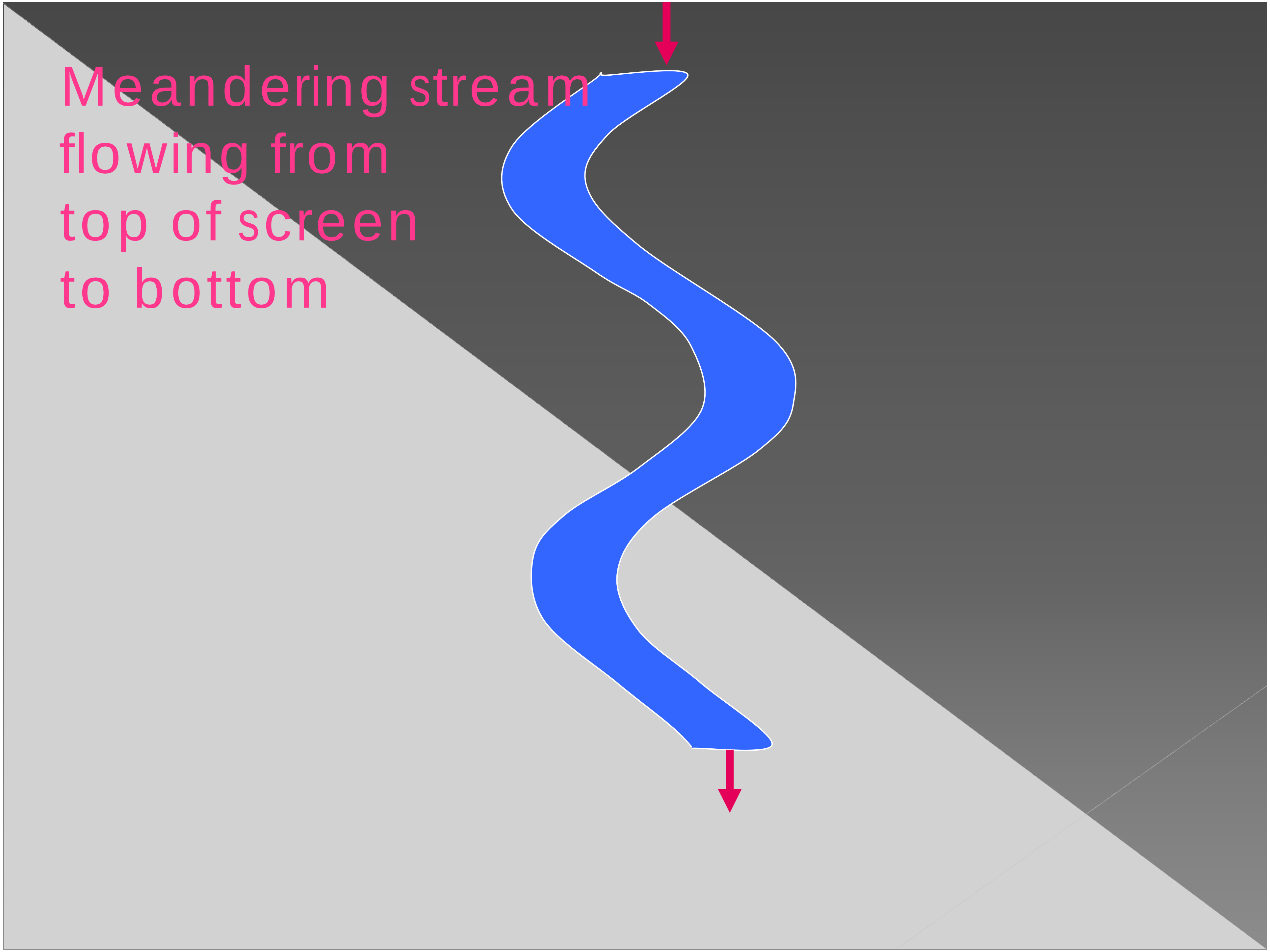
Meandering

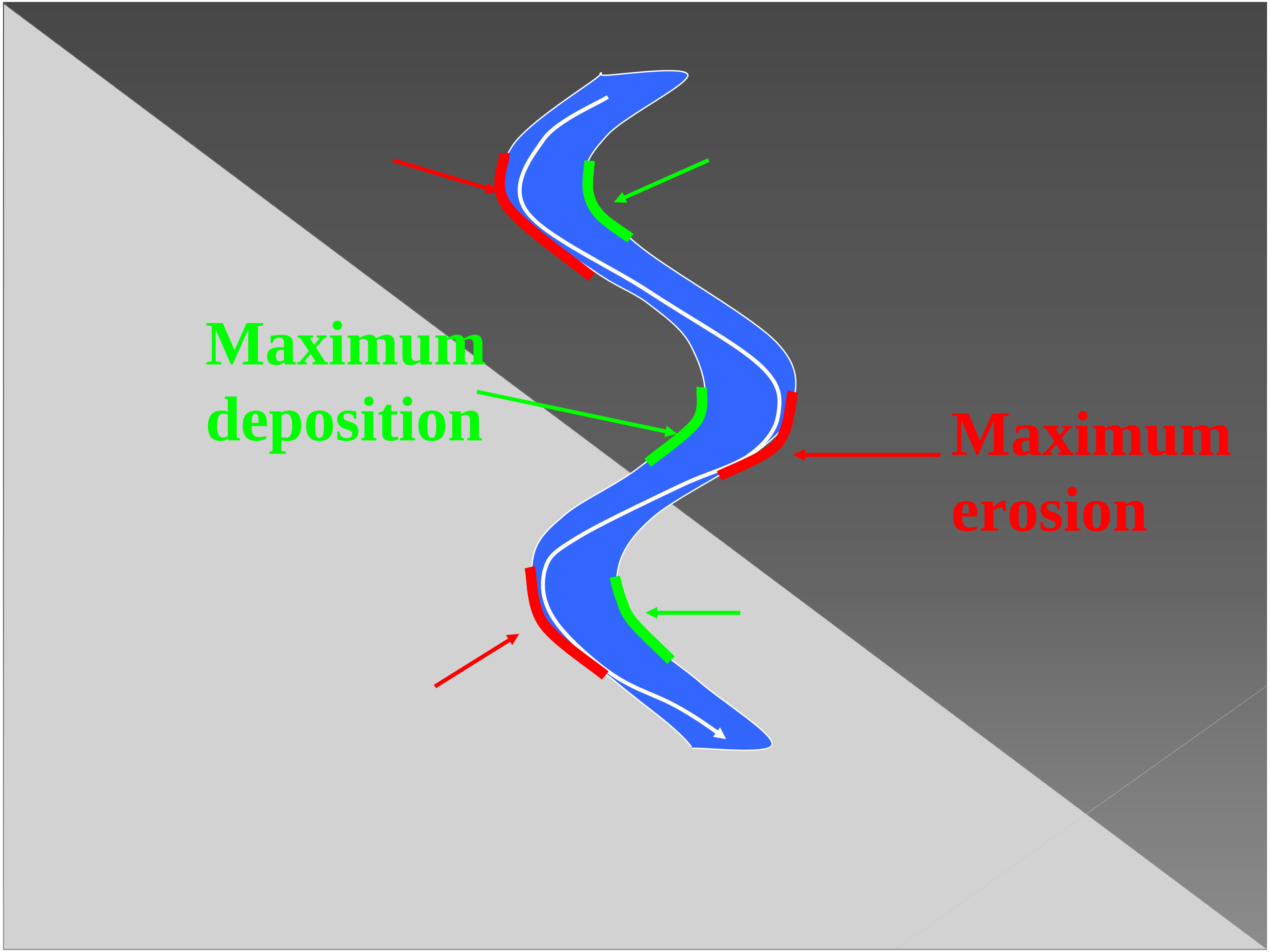
- meander belts

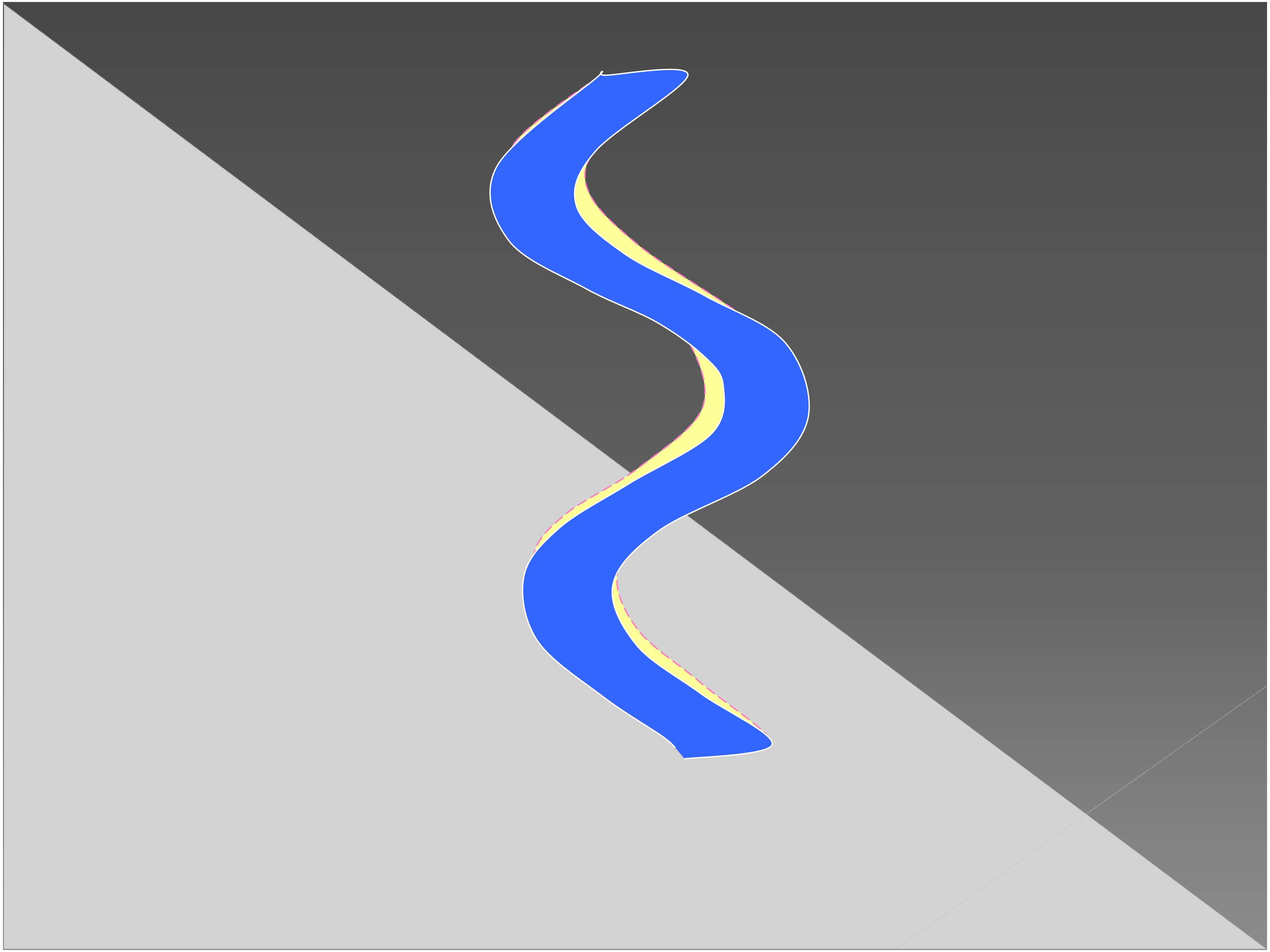
songhua r., china

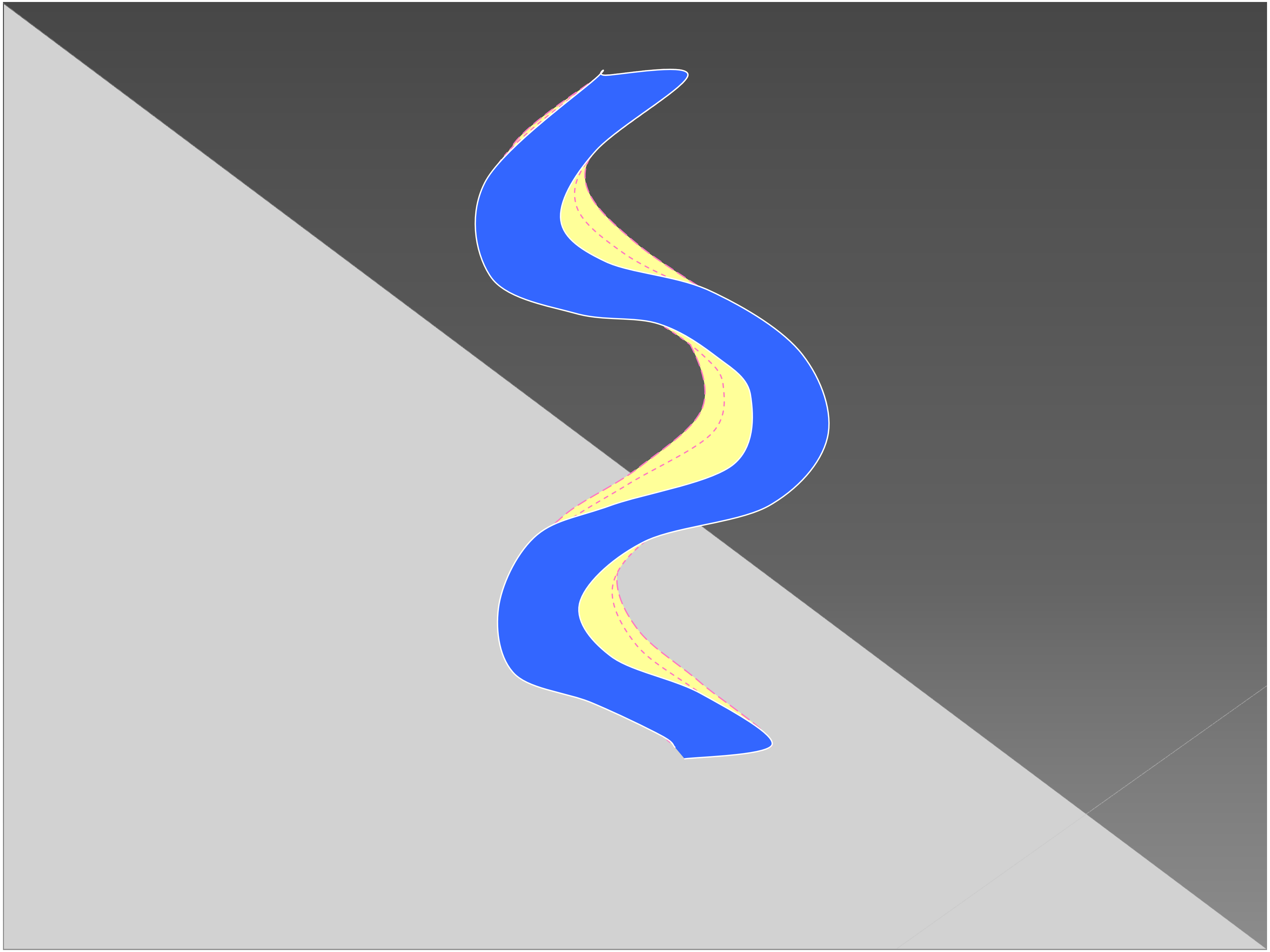
oxbows (sloughs)

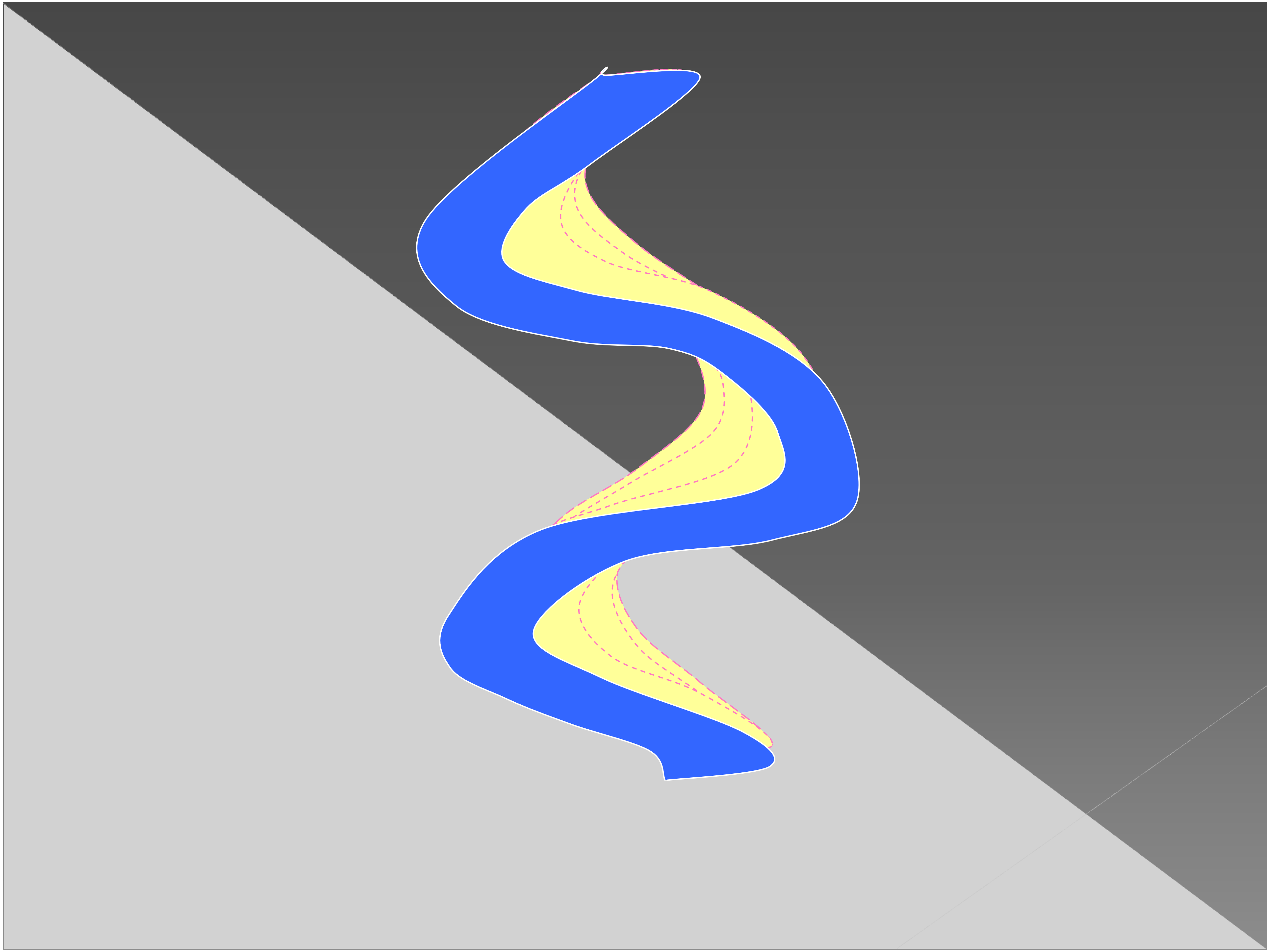


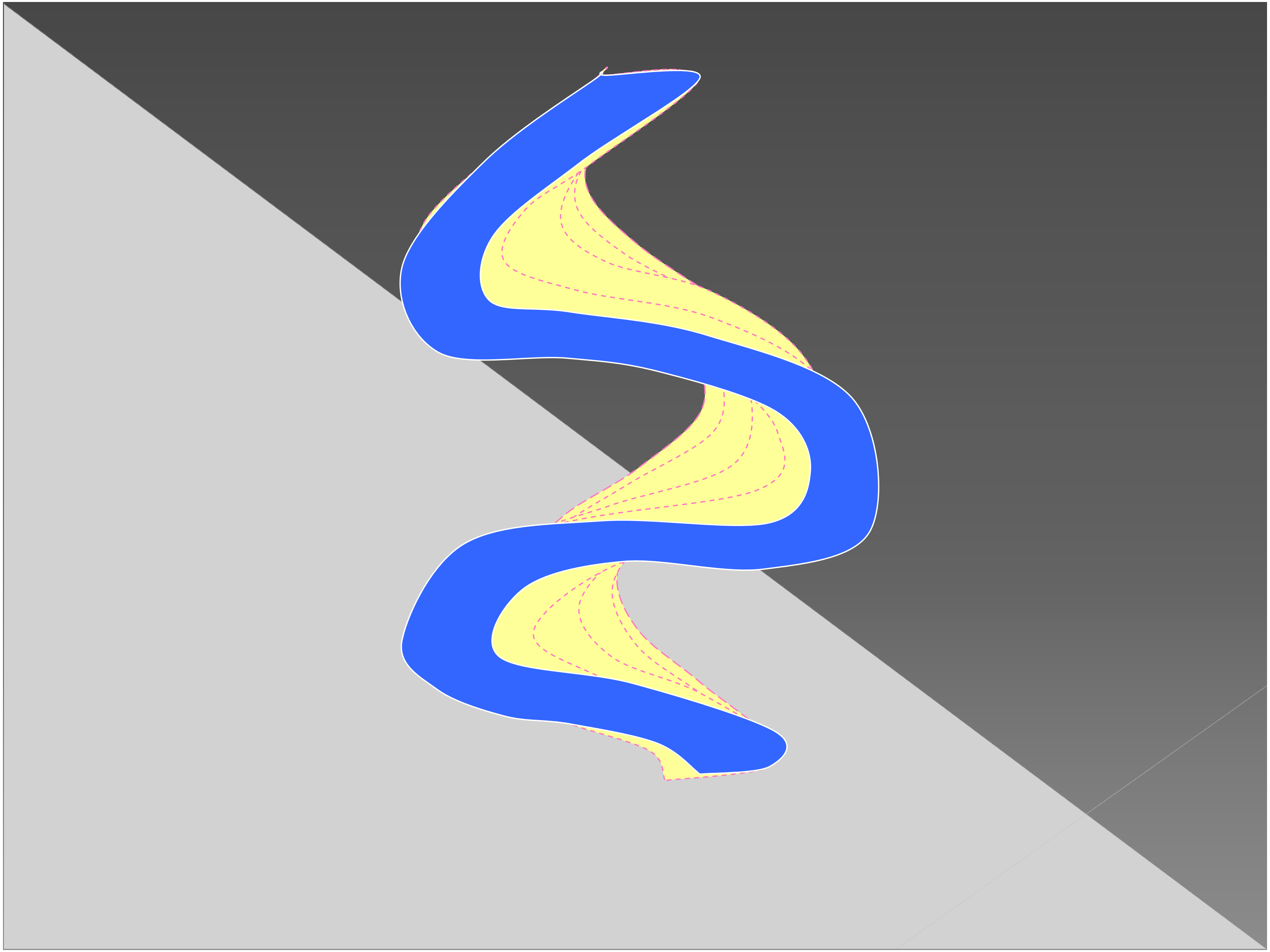

Meandering stream
flowing from
top of screen
to bottom

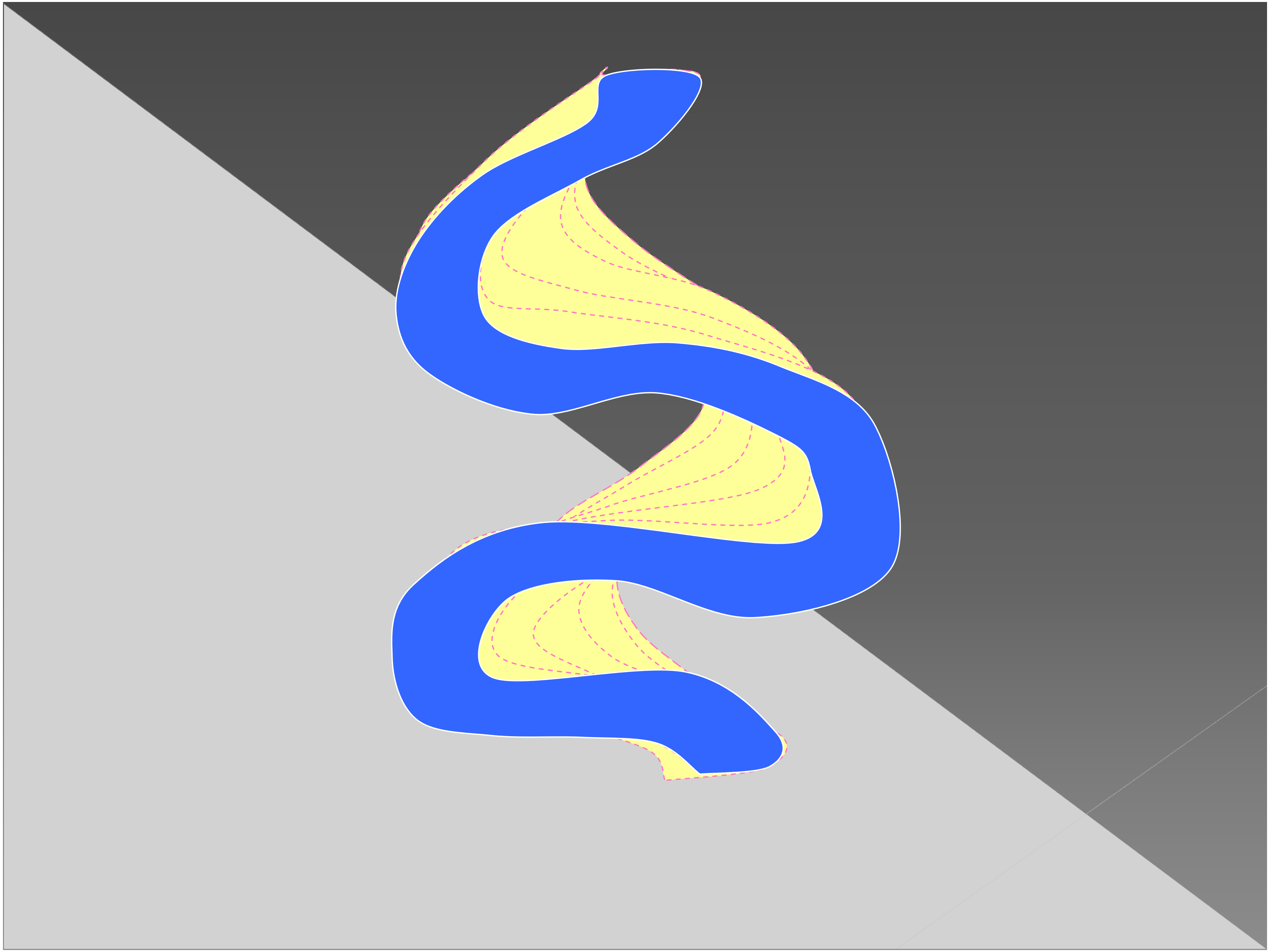

Maximum deposition
Maximum erosion

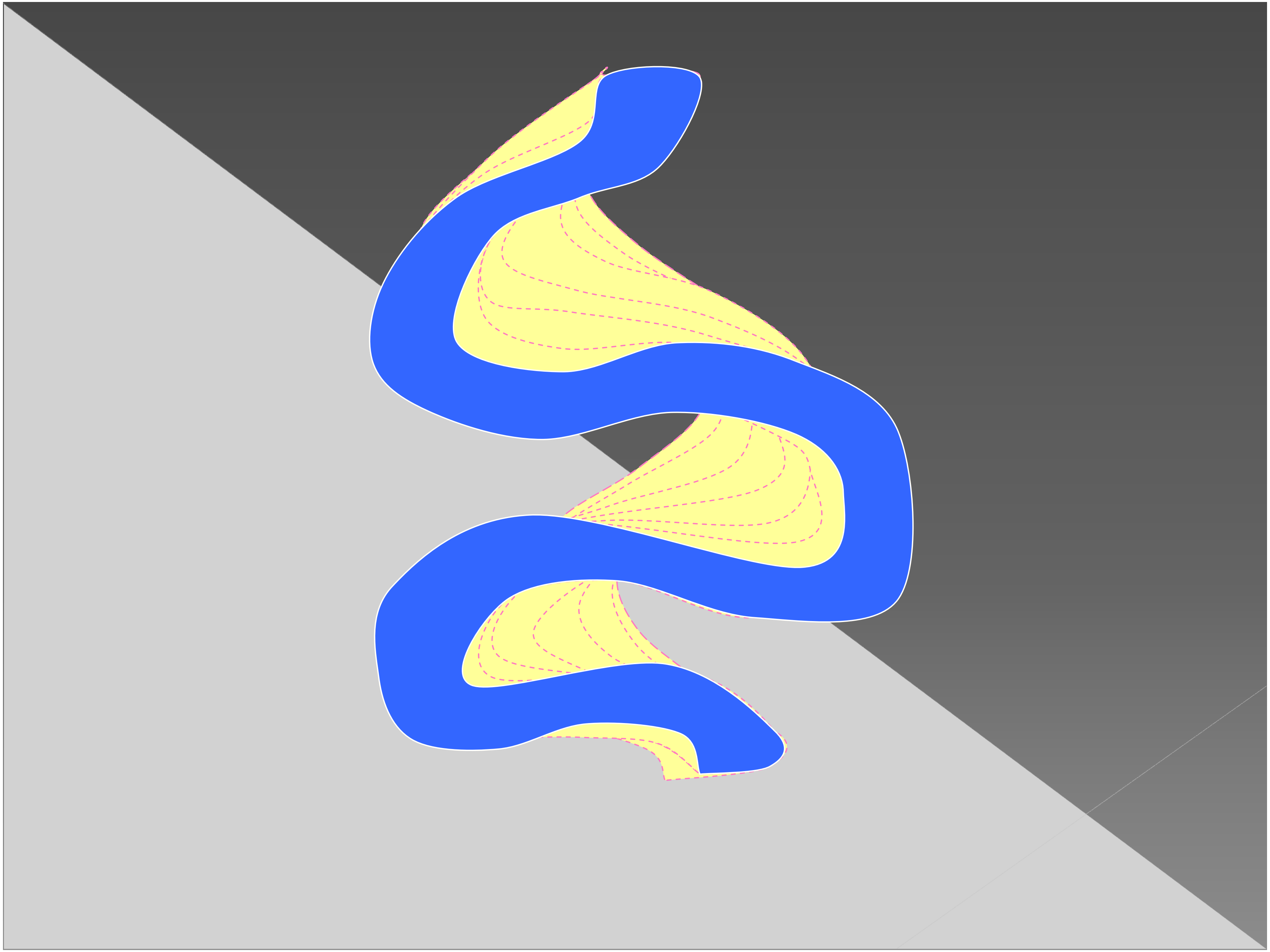


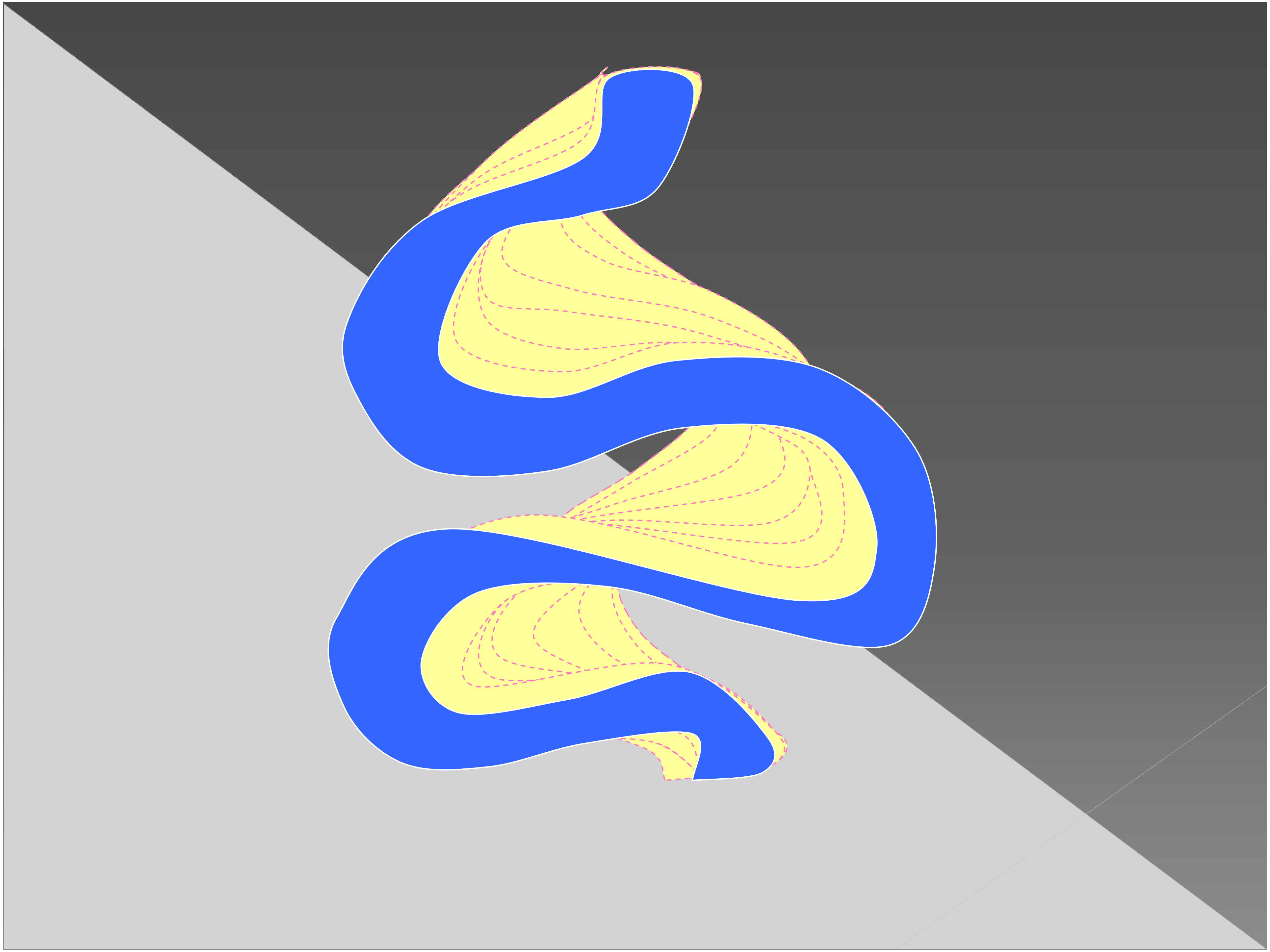


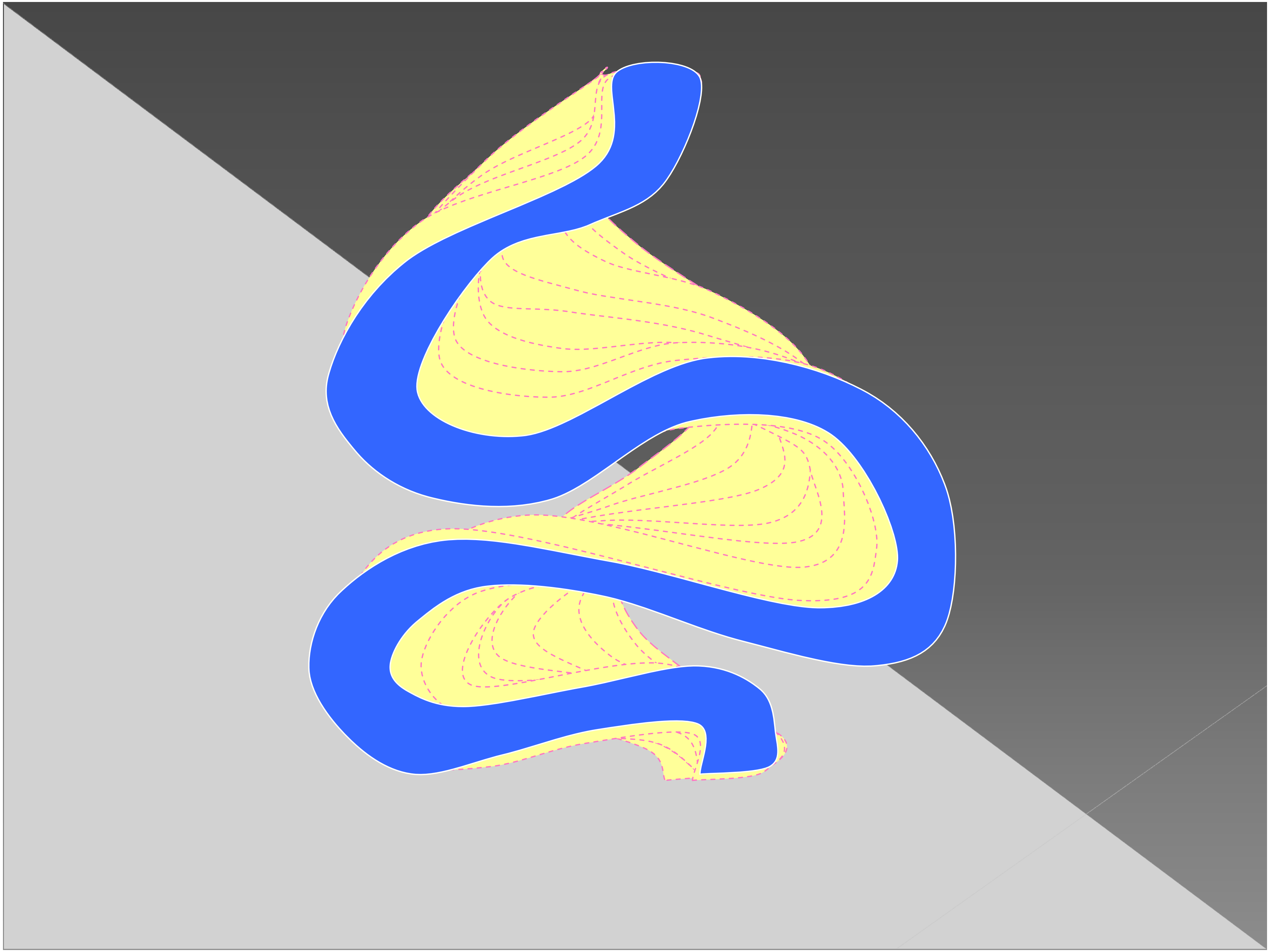


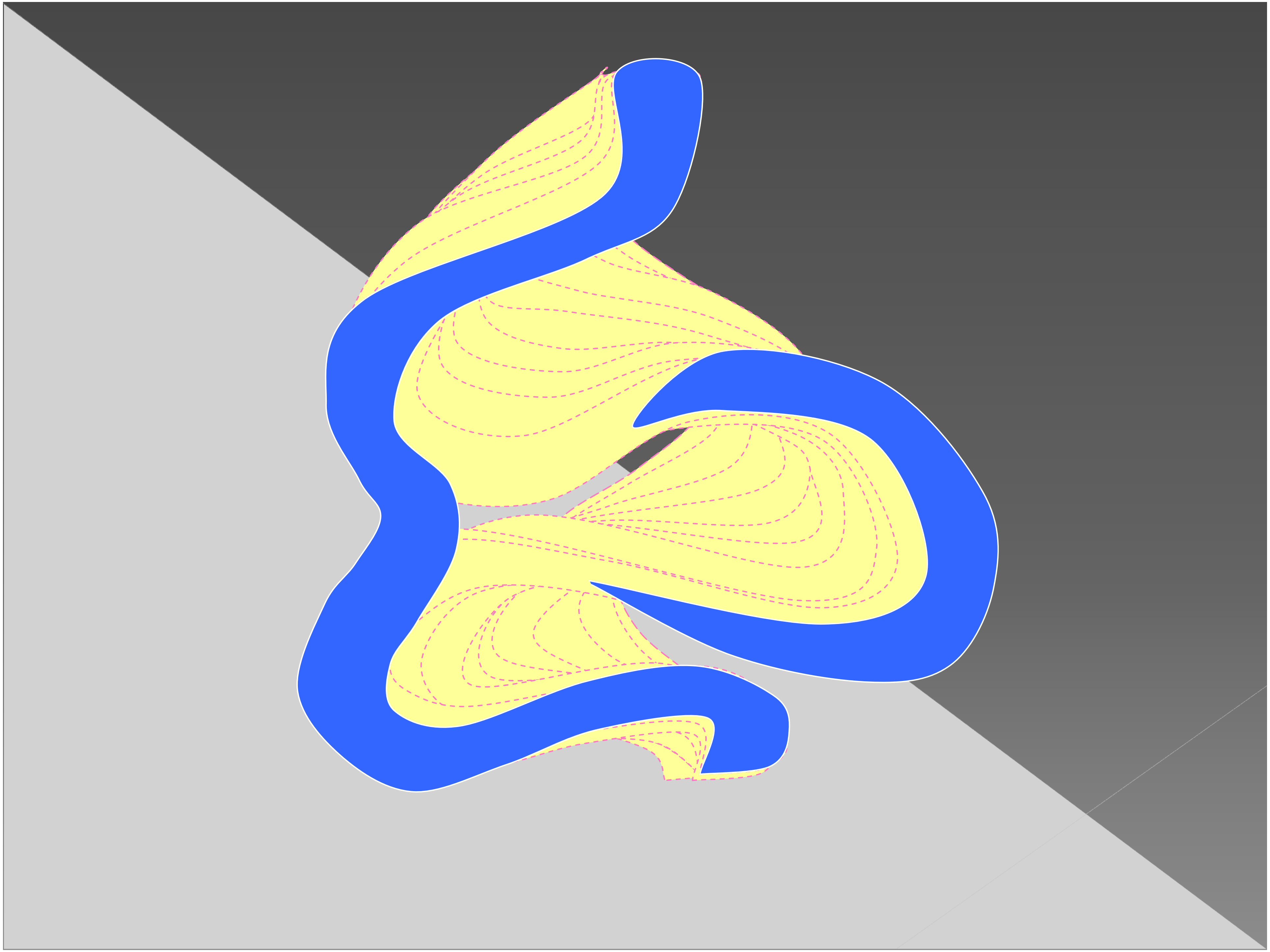


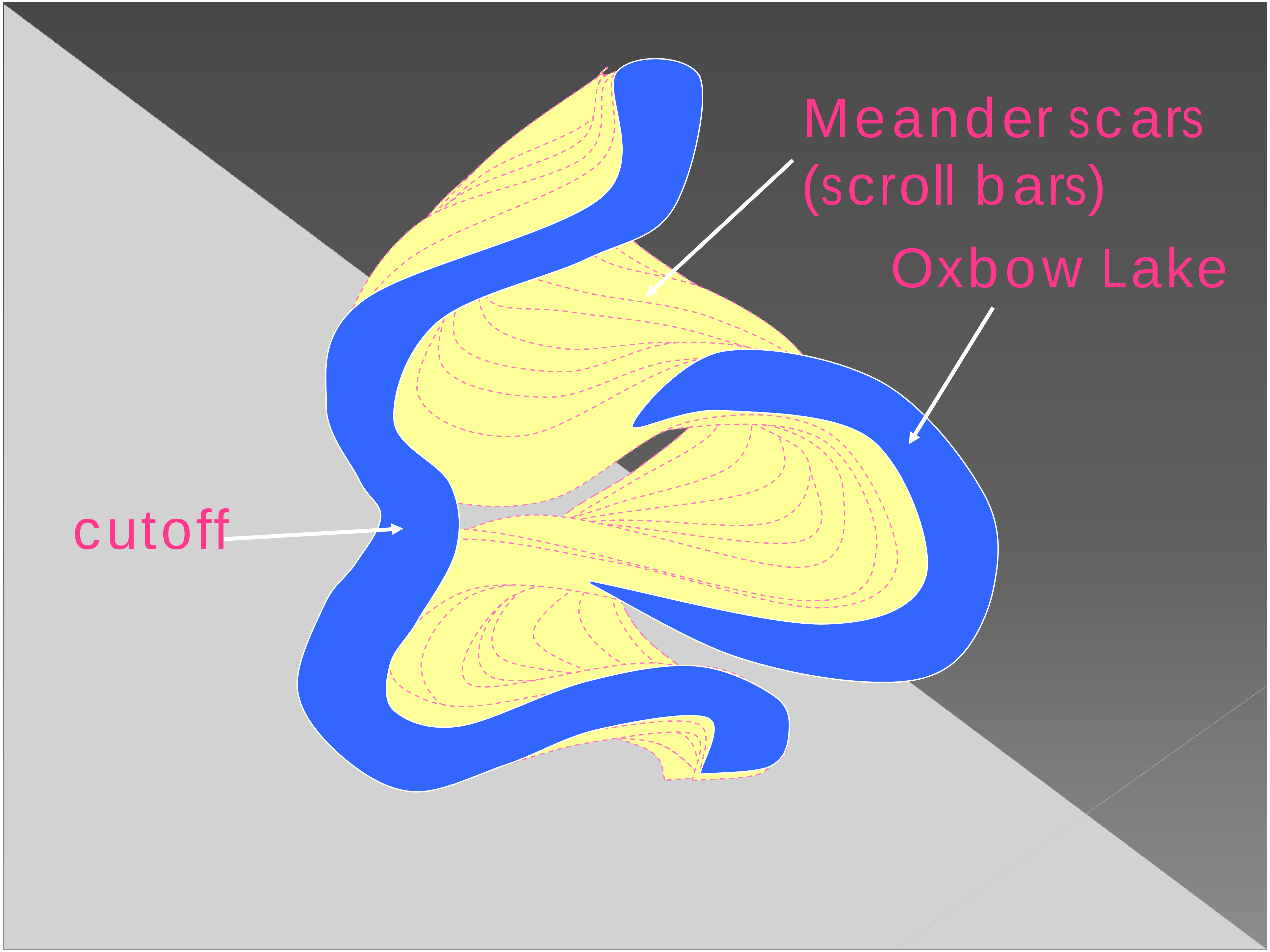




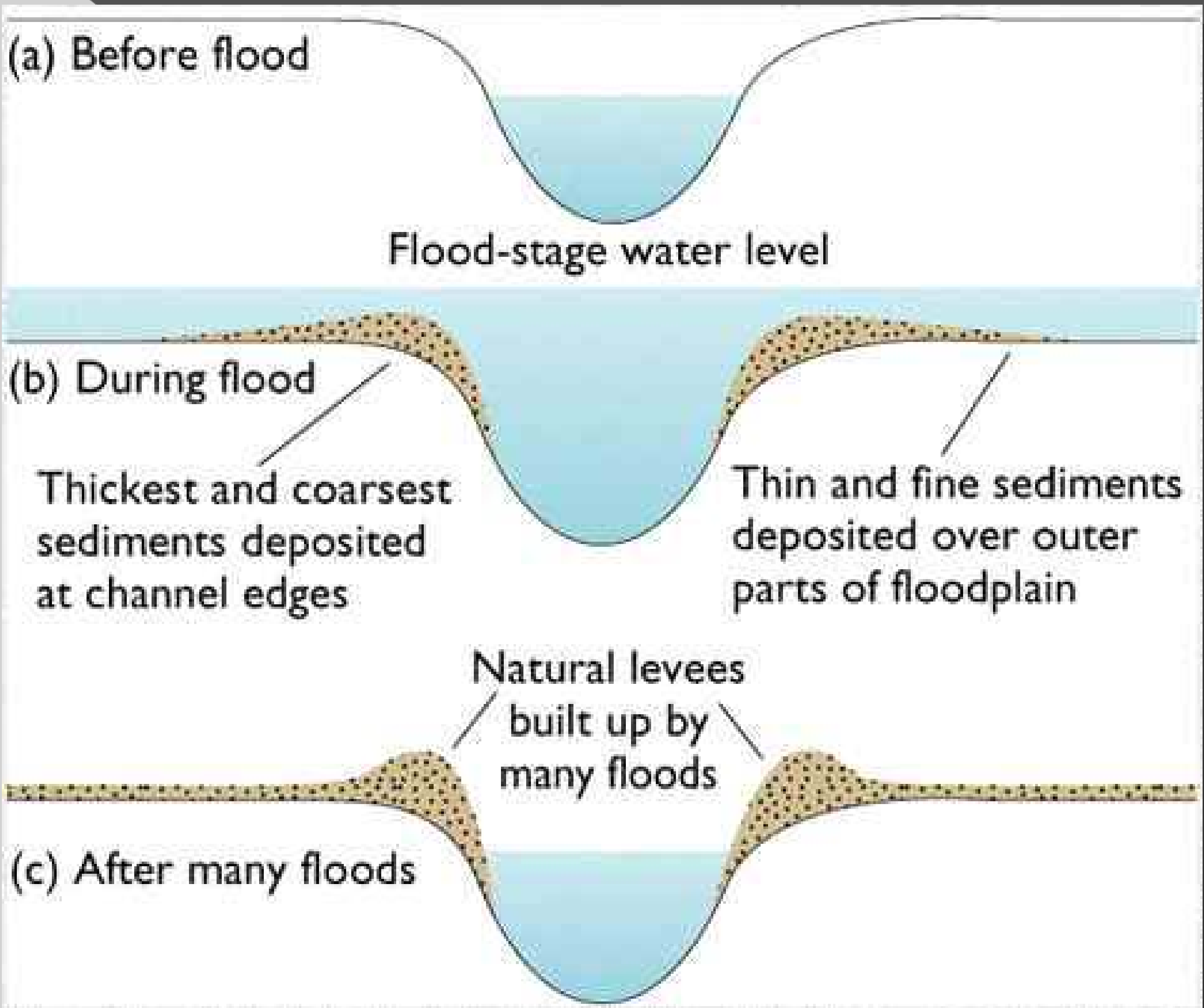






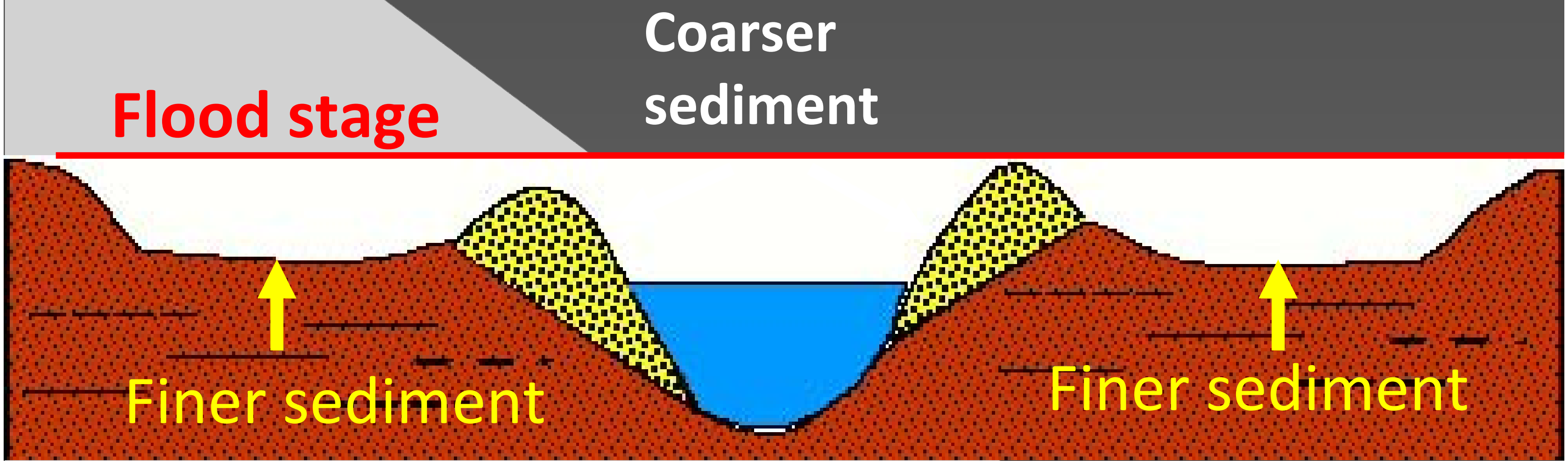

Meander scars
(scroll bars)
Oxbow Lake
cutoff

Flooding & Sedimentation



Flooding & Sedimentation

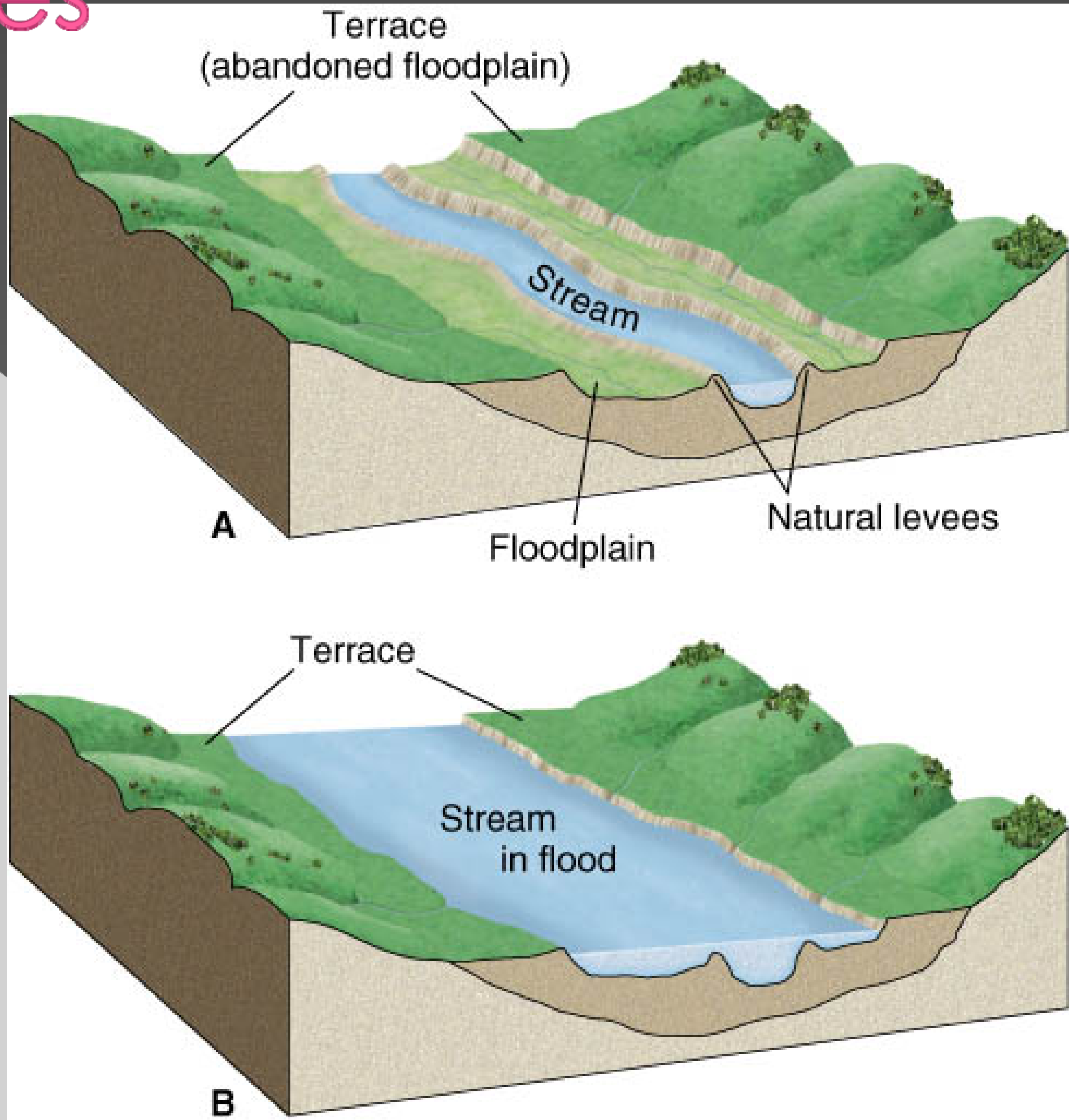
Levee Deposits



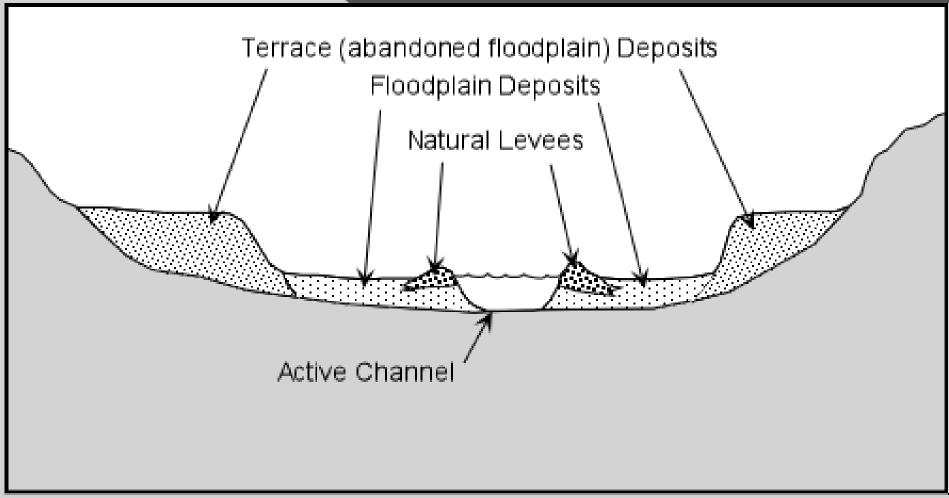
The area adjacent to and outside of the channel serves as an overflow area for excess water and sediment

River terraces

Many stream valleys contain one or more relatively flat alluvial terraces that lie above the floodplain.



River terraces



Profile (longitudinal)

- Slope
  - **difference in elevation/stream length**
- Bed features (secondary measurement)
  - **Description of characteristics such as riffle/pools**

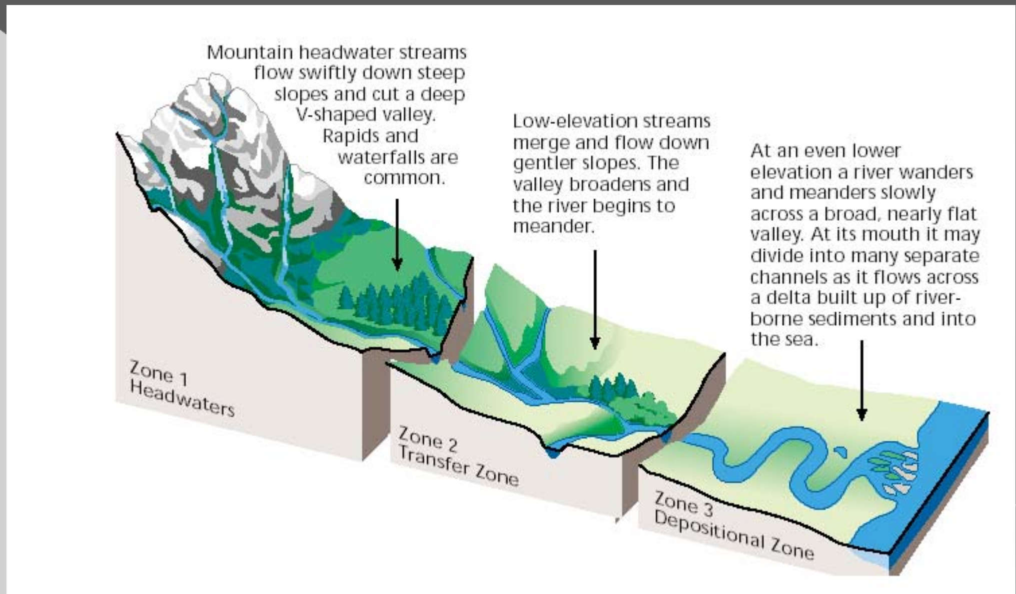
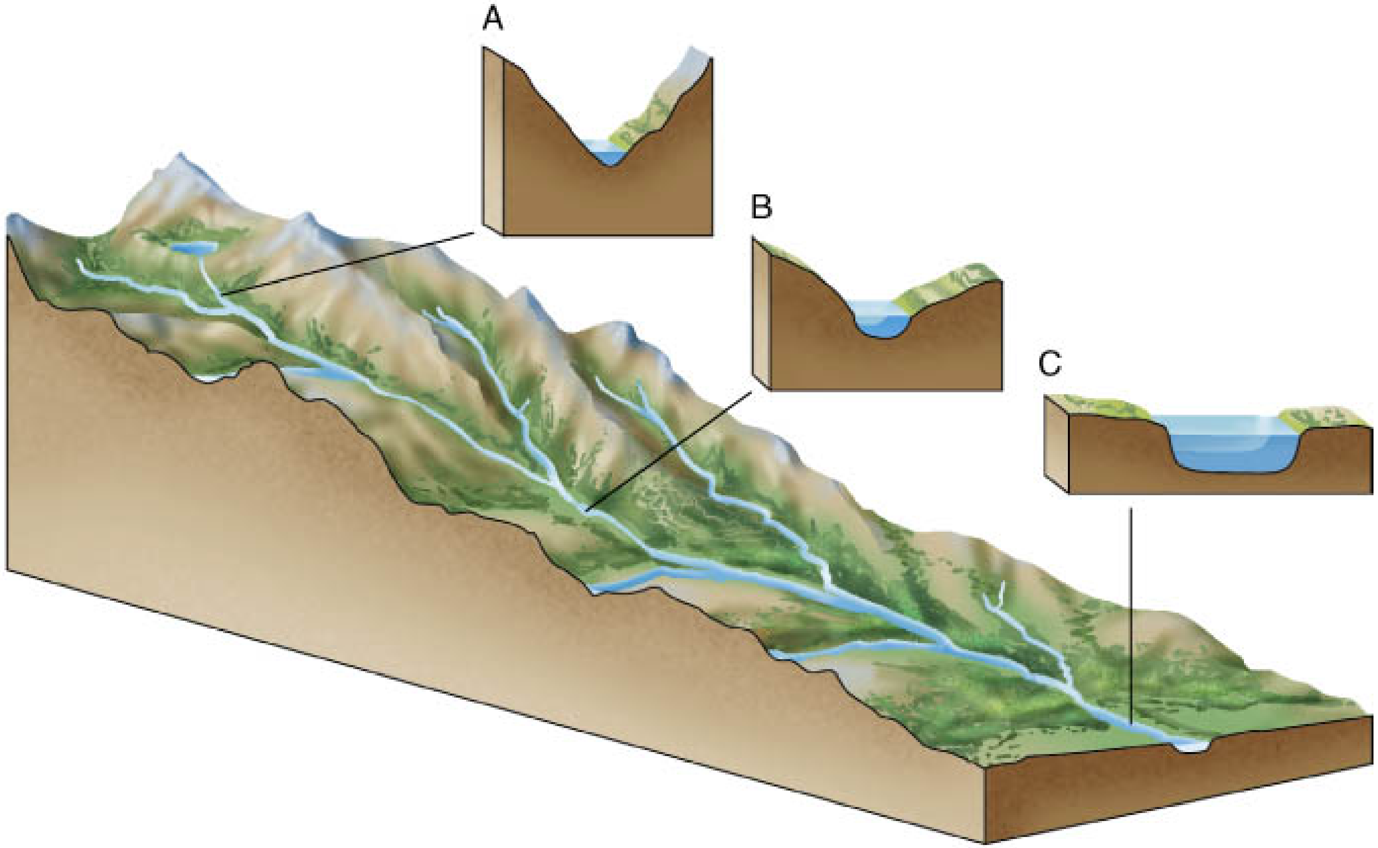
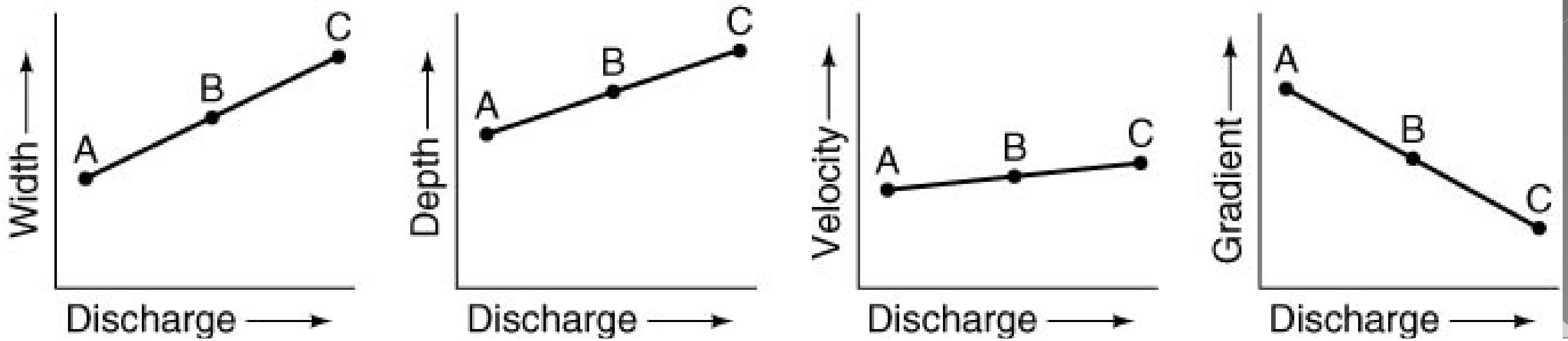


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

major downstream trends

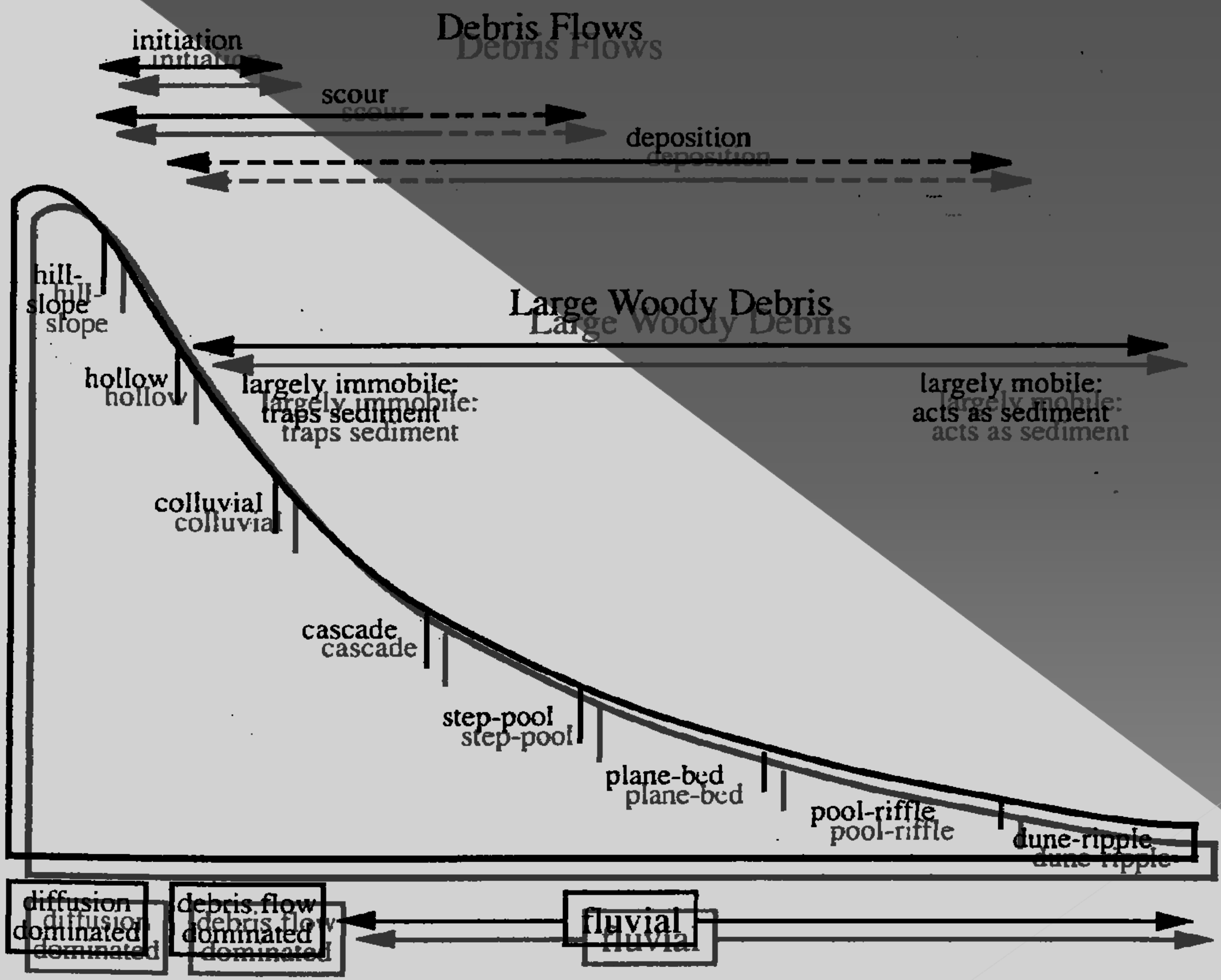
- discharge ↑
- width ↑
- depth ↑
- velocity ↑
- gradient ↓
- grain size ↓

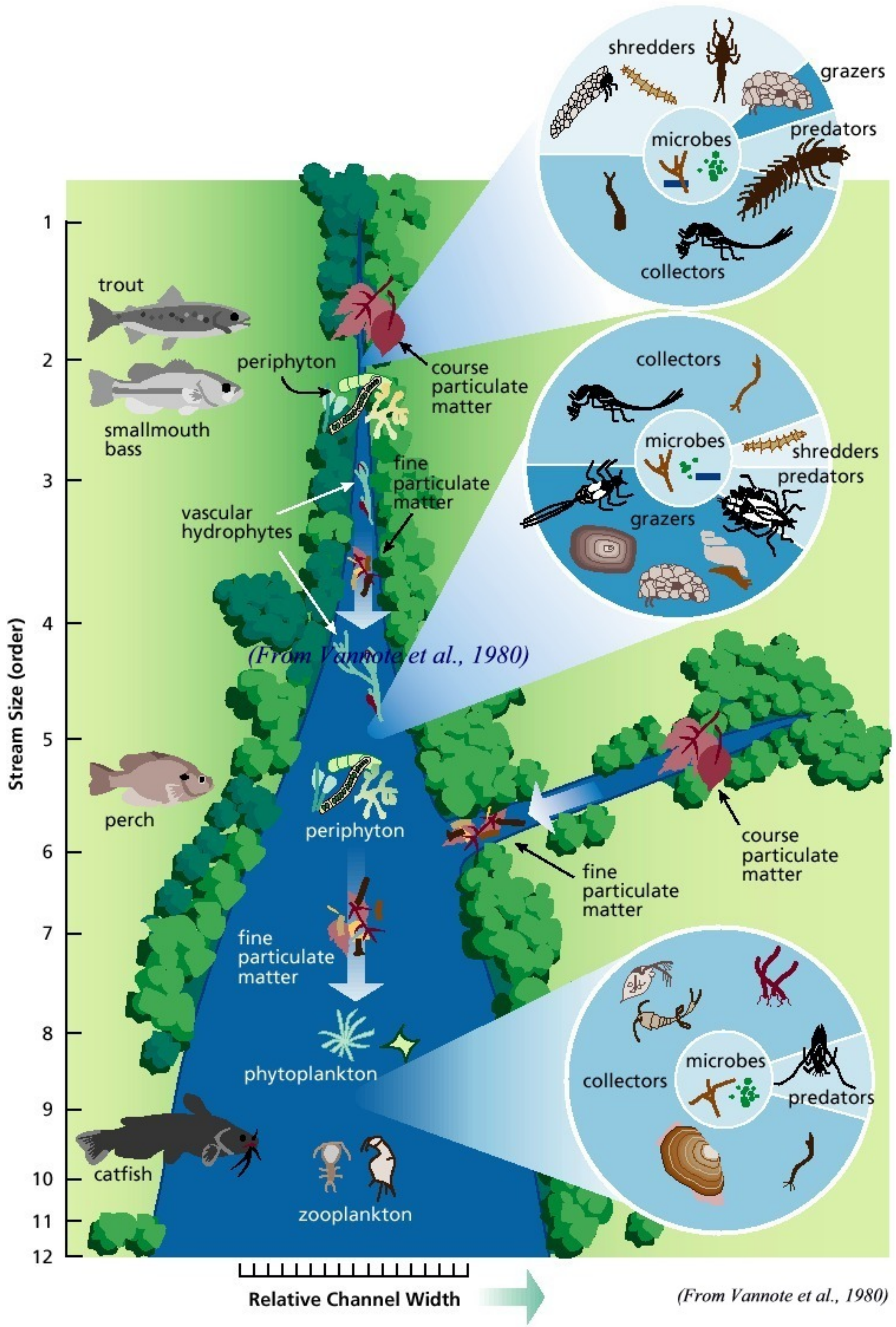




Profile (longitudinal)

- Typical mountain stream





Profile (longitudinal)

River Continuum Concept

-connections from headwaters to lower reaches.
-biological connectivity
-importance of riparian/aquatic connectivity
-aquatic freshwater foodwebs are often based on terrestrial inputs. One of the most important energy sources is terrestrial autotrophic organisms (ie, streambank plants)

Ecological restoration of stream system often begins with **engineering.**

Need to establish sinuosity.

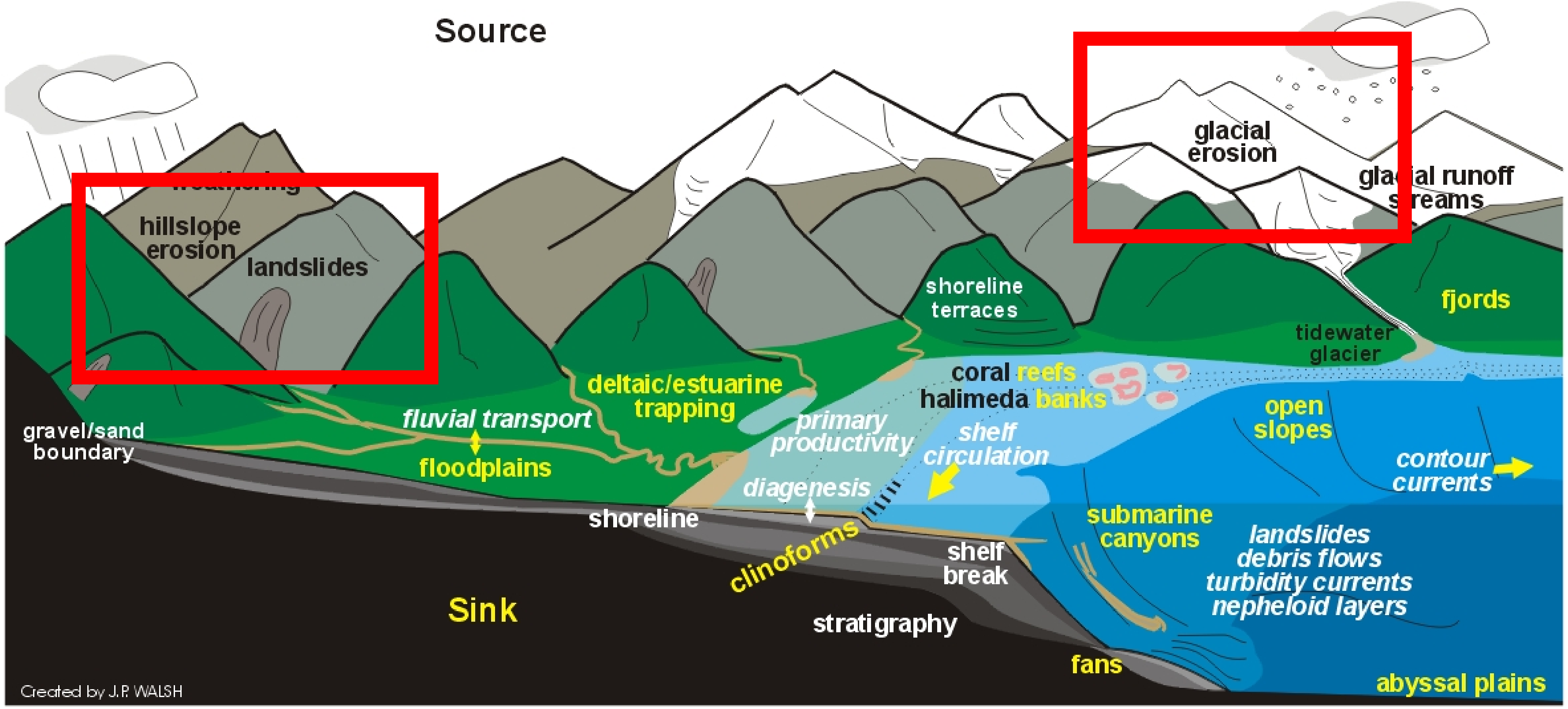
Then substrate.

Manage flow.

Establish natural riparian vegetation.

erosion

- moving away from the source…

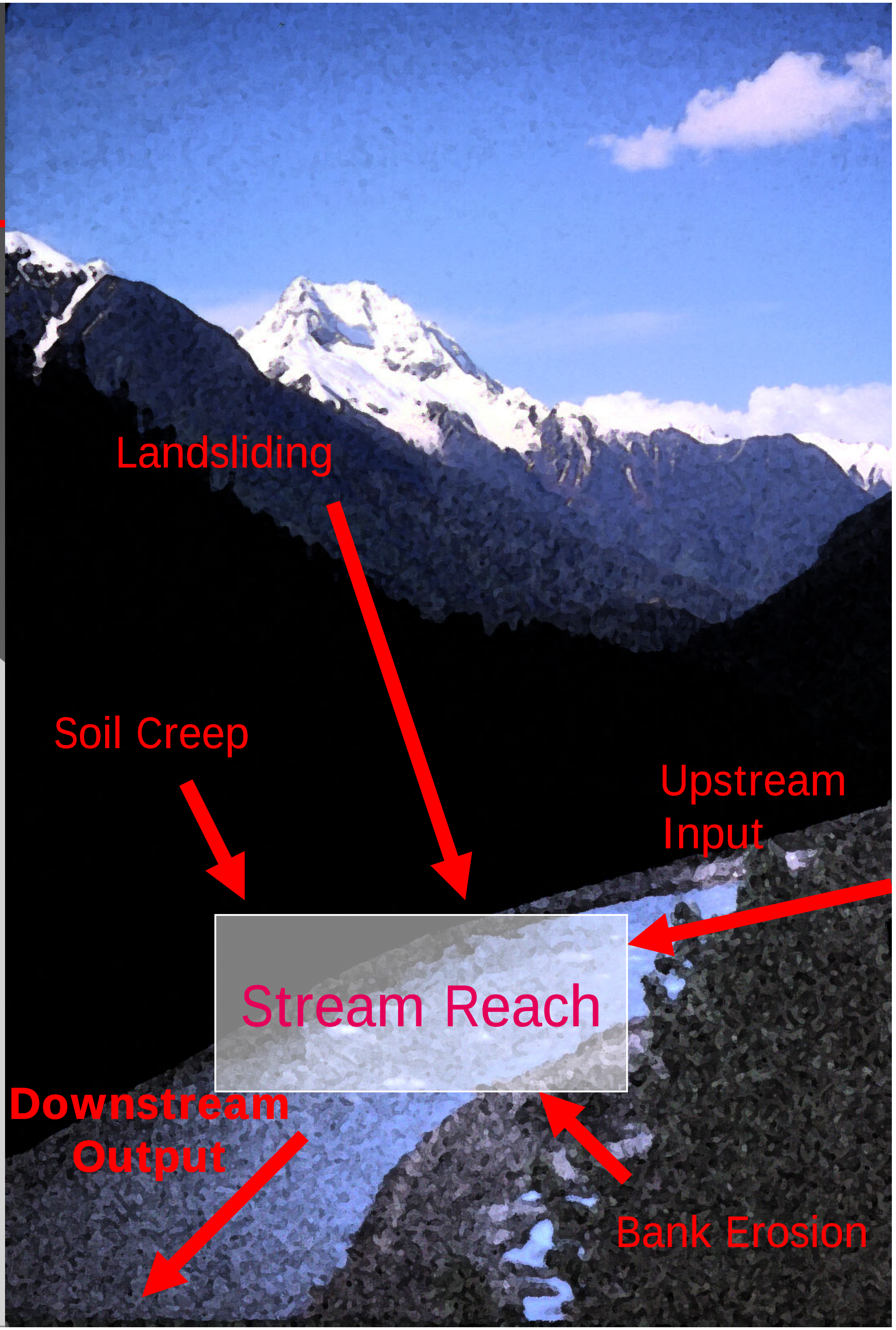


Sediment Budget

- along a stream reach

$$I - O = \Delta S$$

Sediment inputs from upstream and across channel banks are balanced by either downstream sediment transport or changes in sediment storage.



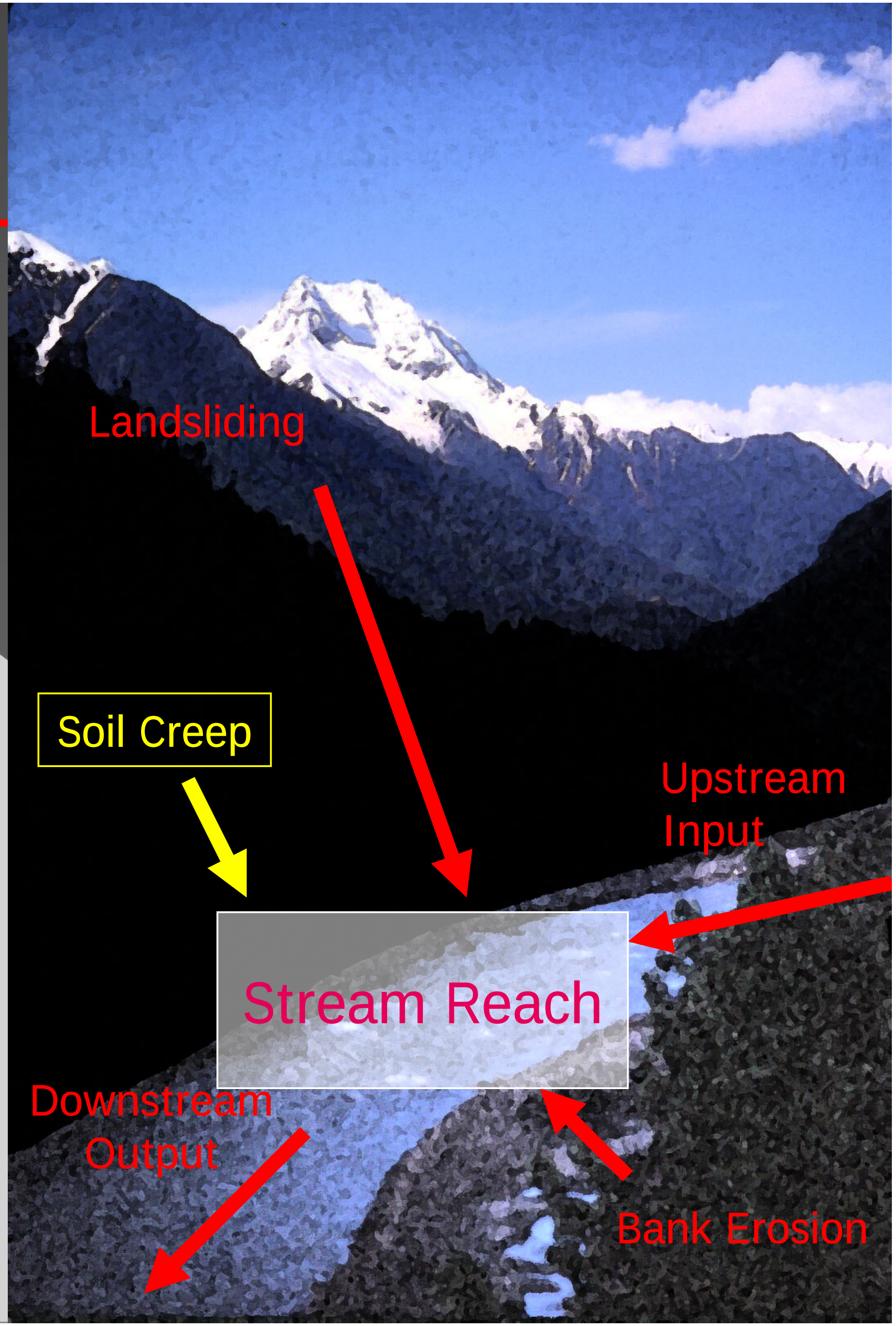
Erosional Processes

- Soil “Creep”
- Overland Flow
- Landslides
- Glaciers
- River Incision
- Bank Erosion

Soil Creep

Slow, steady input of material across channel banks, or delivered to valley bottom.

Typical rates of 0.1 to 1 mm yr^{-1}.



Erosional Processes

- Soil “Creep”
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Erosion by overland flow occurs once enough flow accumulates to overcome the *erosion resistance* of the ground surface.

Overland Flow

Erosion by overland flow is rare in forested mountain landscapes because:

- rainfall tends to infiltrate into the ground
- the ground has substantial erosion resistance due to vegetation

Erosion by overland flow is most common in disturbed or semi-arid landscapes

Erosional Processes

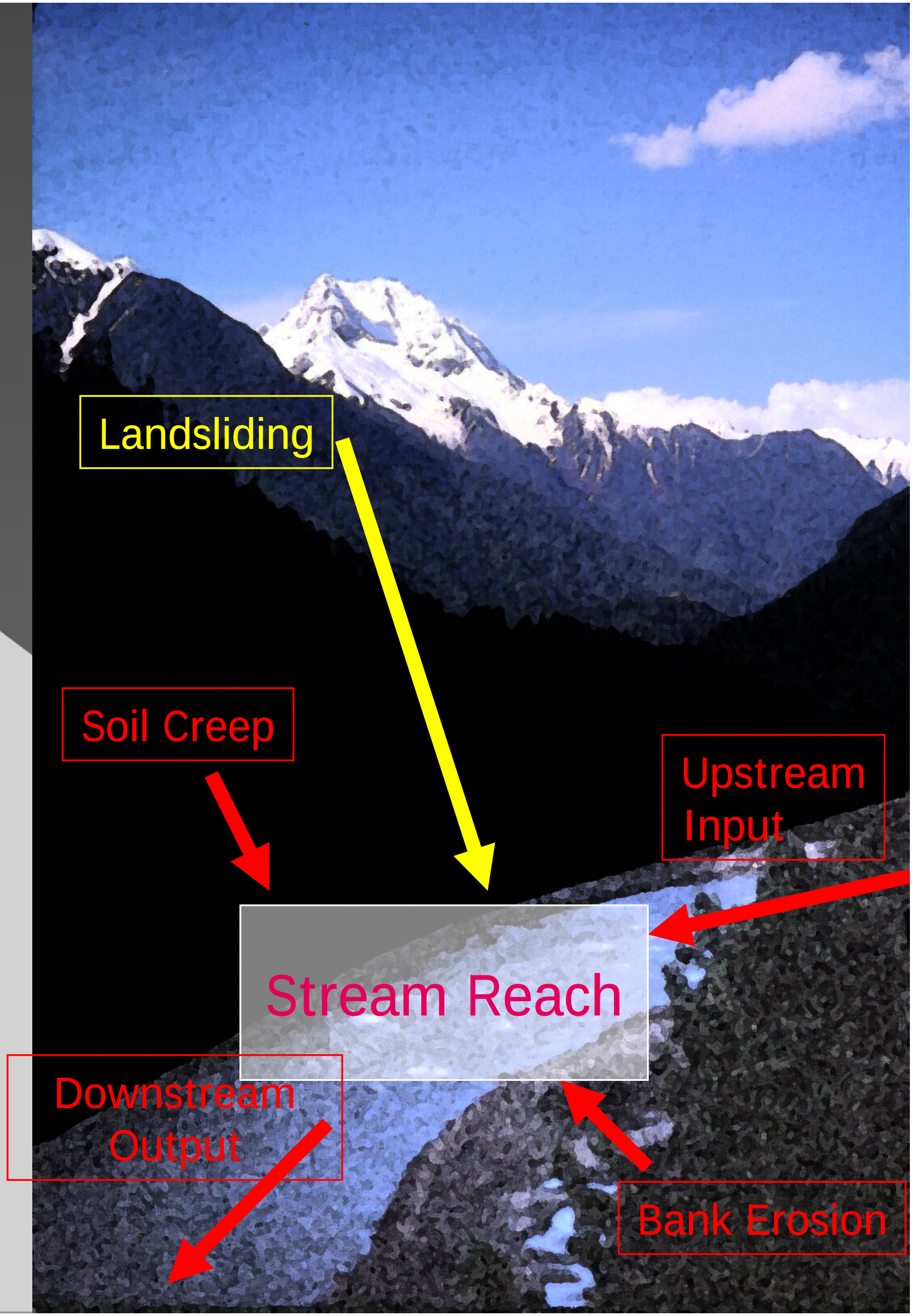
- Soil "Creep"
- Overland Flow
- Landslides
- Glaciers
- River Incision
- Bank Erosion

Landslides involve the downslope movement of soil and/or rock under the influence of gravity and may be either slow and gradual or rapid and catastrophic.

Landsliding

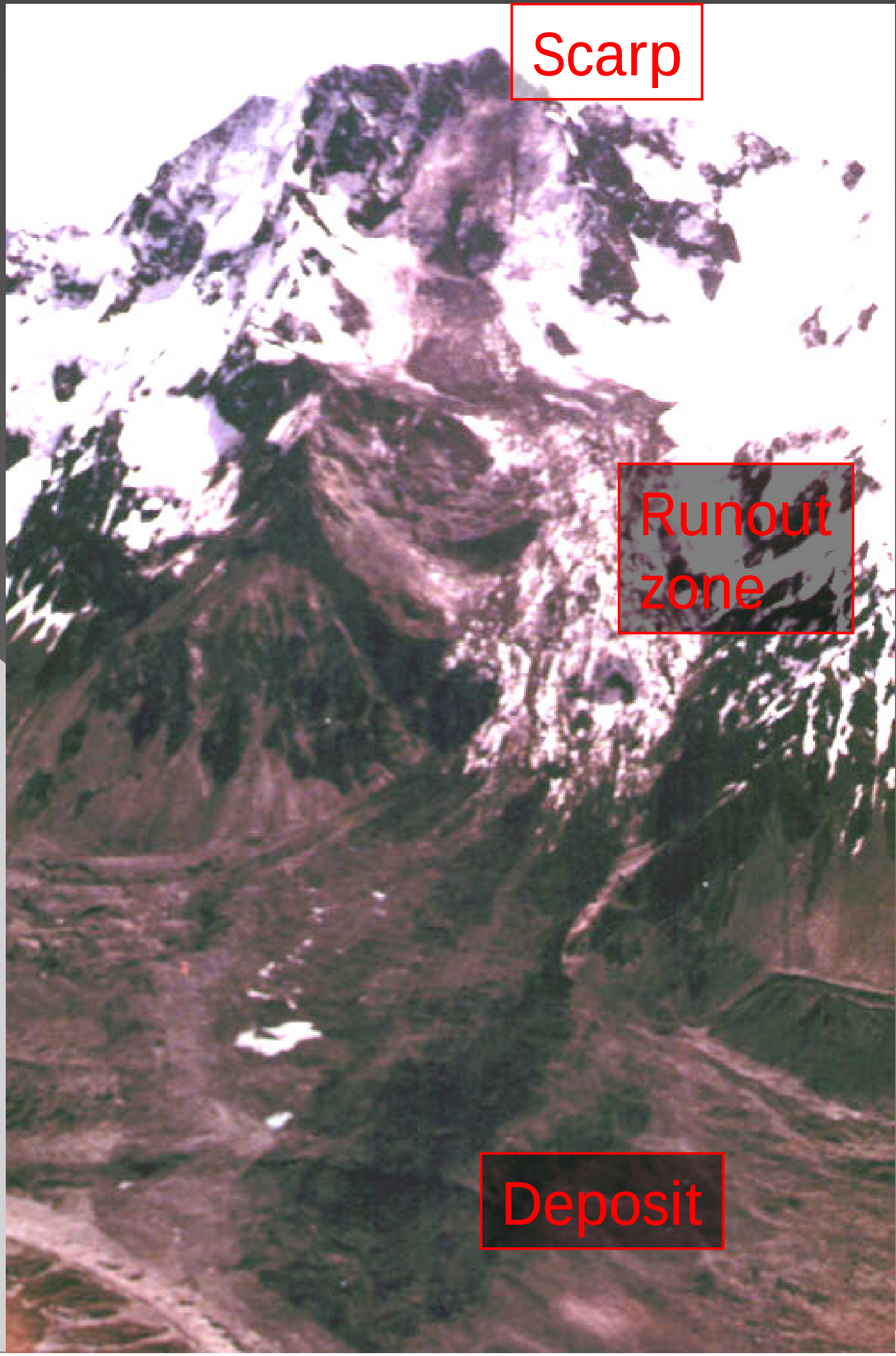
Rapid, infrequent inputs of large volumes of sediment.

Rates of delivery set by landslide frequency, which is often centuries to millennia at a point.



landslides

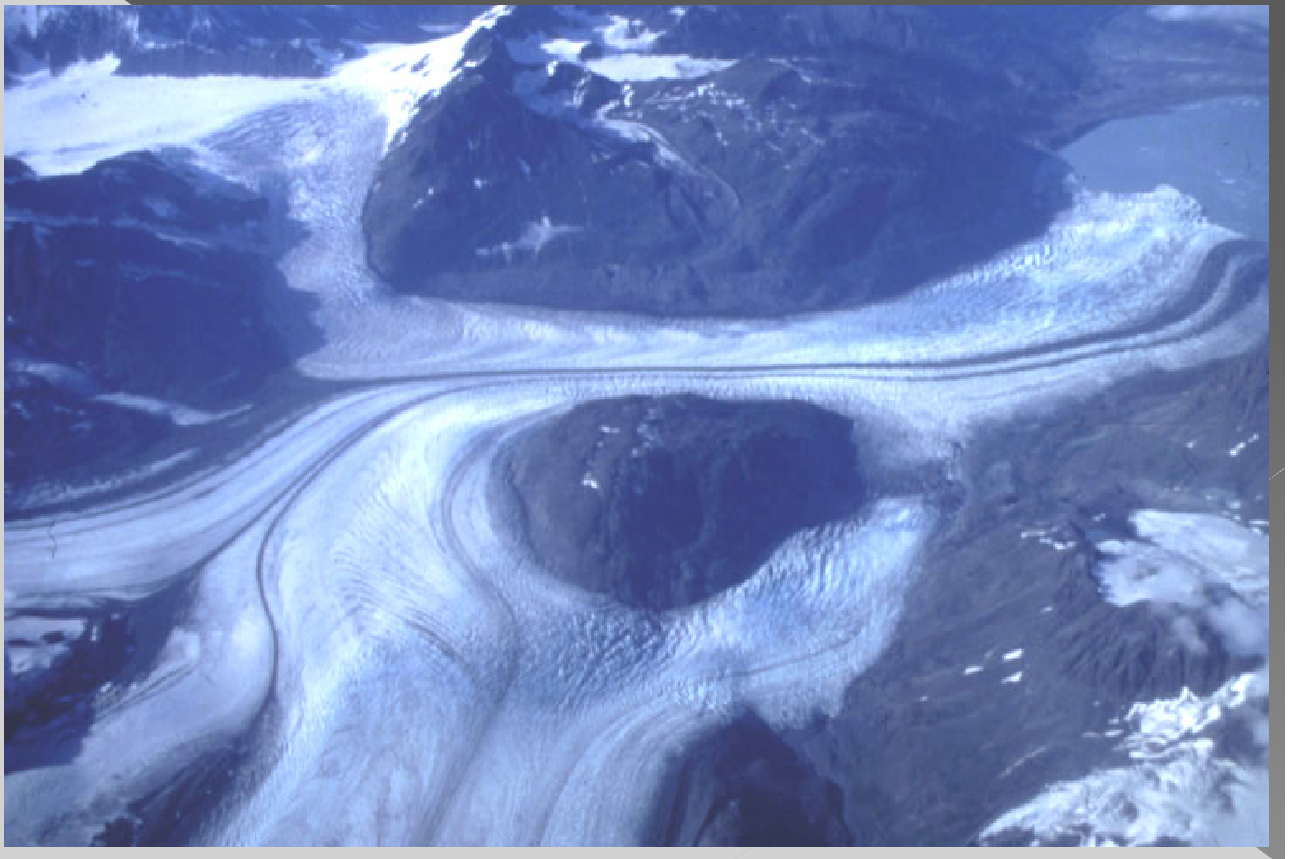
- **Bedrock landslides** can limit the relief of mountain ranges
- earth flows: some internal deformation
- typically slow
- relatively little water
- **Soil landslides**
- debris flows: lots of internal deformation
- rapid
- relatively high water content
- fluid-like flow



Erosional Processes

- Soil “Creep”
- Overland Flow
- Landslides
- Glaciers
- River Incision
- Bank Erosion

Glaciers can both entrain loose surface materials and gouge deeply into bedrock.



Glacial Erosion

Rapid erosion of material from above perennial snow line.

Rates can exceed 10 mm yr^{-1}.

Processes of erosion and rates depend on temperature, glacier size, precipitation rate, etc...

Erosional Processes

- Soil “Creep”
- Overland Flow
- Landslides
- Glaciers
- River Incision
- Bank Erosion

Rivers can carve deeply into bedrock and such incision provides another source of sediment.

In the world there is nothing more submissive and weak than water. Yet for attacking that which is hard and strong nothing can surpass it.

- Lao-Tzu, 6th century B.C.

River Incision

Erosion = f (discharge, channel width, slope)

More water in a narrower channel down a steeper slope means faster river incision

Rates of bedrock river incision typically range from <0.01 mm yr^{-1} to 1 mm yr^{-1}, but can exceed 5 mm yr^{-1} in extreme topography.

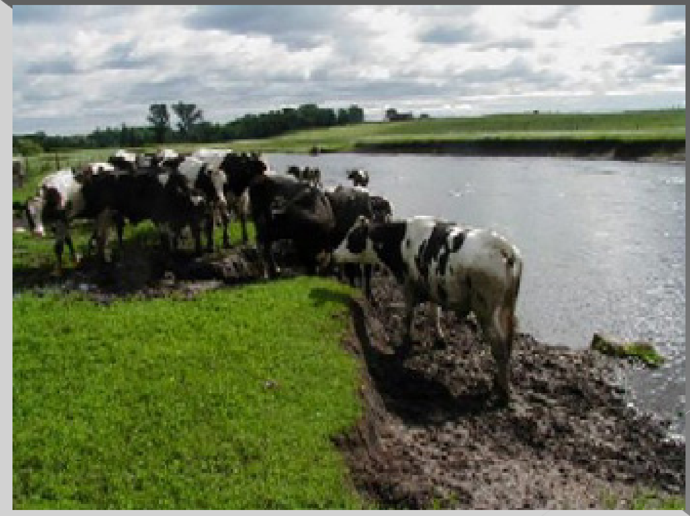
Erosional Processes

- Soil "Creep"
- Overland Flow
- Landslides
- Glaciers
- River Incision
- Bank Erosion

Bank erosion recycles material stored on the valley bottom, typically in the floodplain.

Potential causes of bank erosion

- Vegetative clearing
- Channelization
- Streambed disturbance
- Dams
- Levees
- Soil exposure or compaction
- Overgrazing
- Dredging for mineral extraction
- Woody debris removal
- Piped discharge
- Water withdrawal



Measuring bank erosion potential

Measure the following variables then rate from very low to extreme

- Bank height/bankfull height
- Root depth/bank height
- % root density
- Bank angle (degrees)
- % Surface protection
- Soil stratification
- Particle size

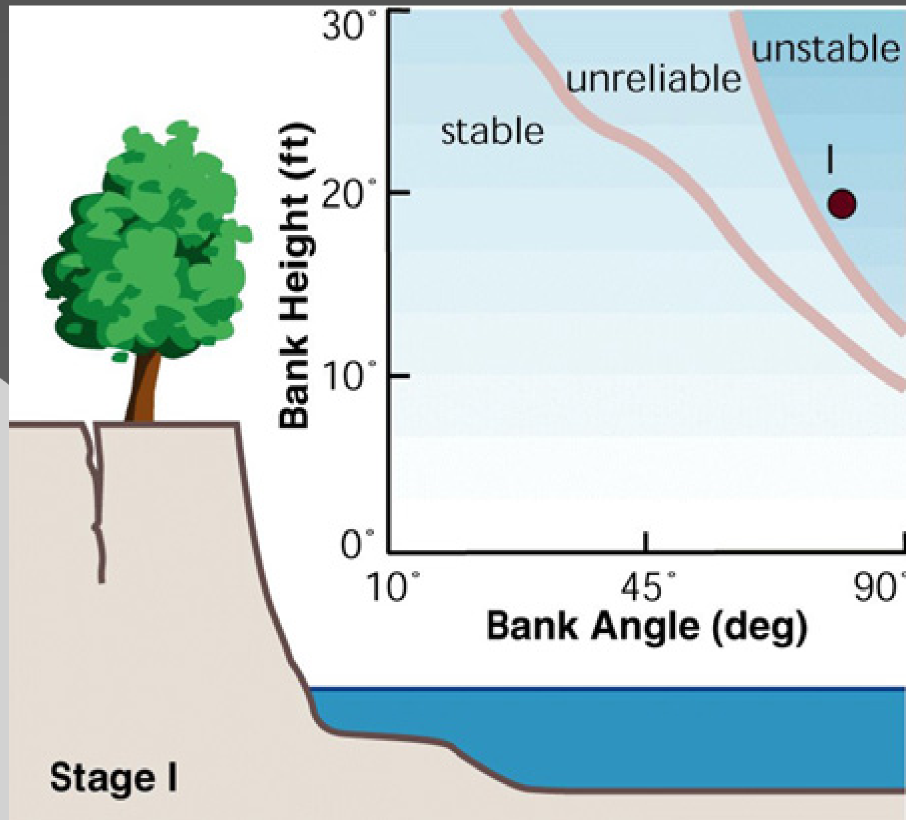


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

Restoration Techniques for Accelerated Bank Erosion

- Bank shaping
- Fascines
- Live Staking
- Root wads

Bank shaping

Purpose

- Alter the bank angle so that bank angle (degrees) that it is stable

Efficacy

- Usually necessary before vegetation can be added to the bank

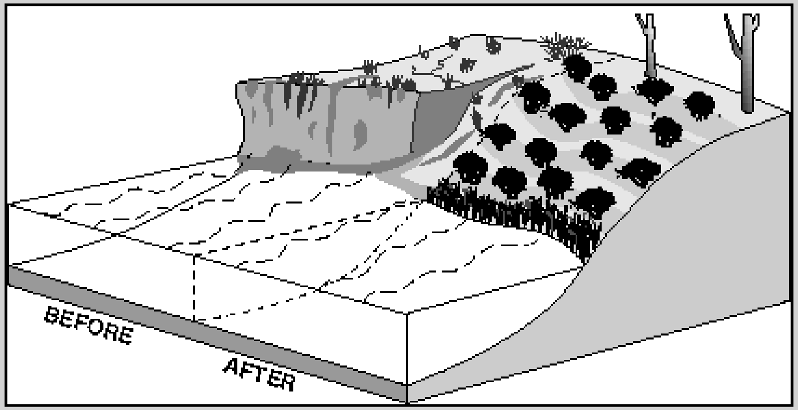


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

Fascines

- Live shrubs (willow) bundled together with rope
- Purpose: Vegetate eroded banks providing stabilization and habitat (root density and soil surface protect

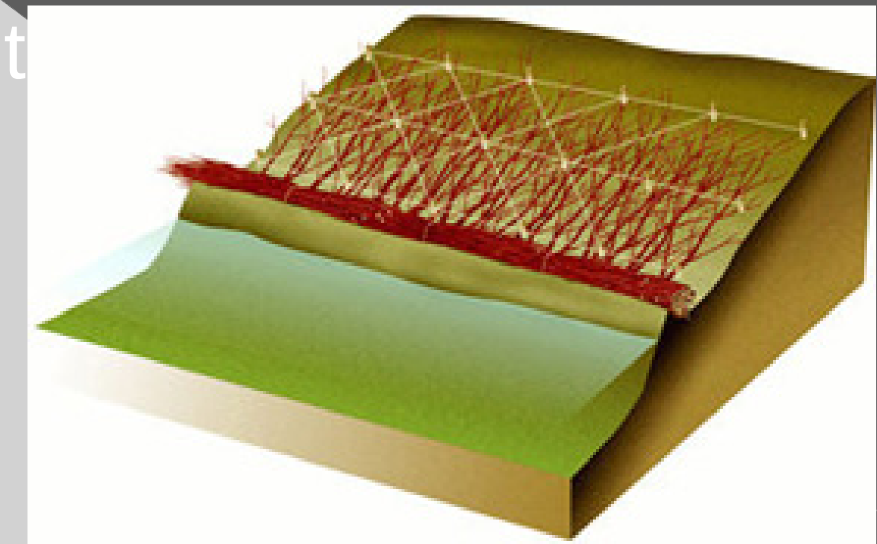
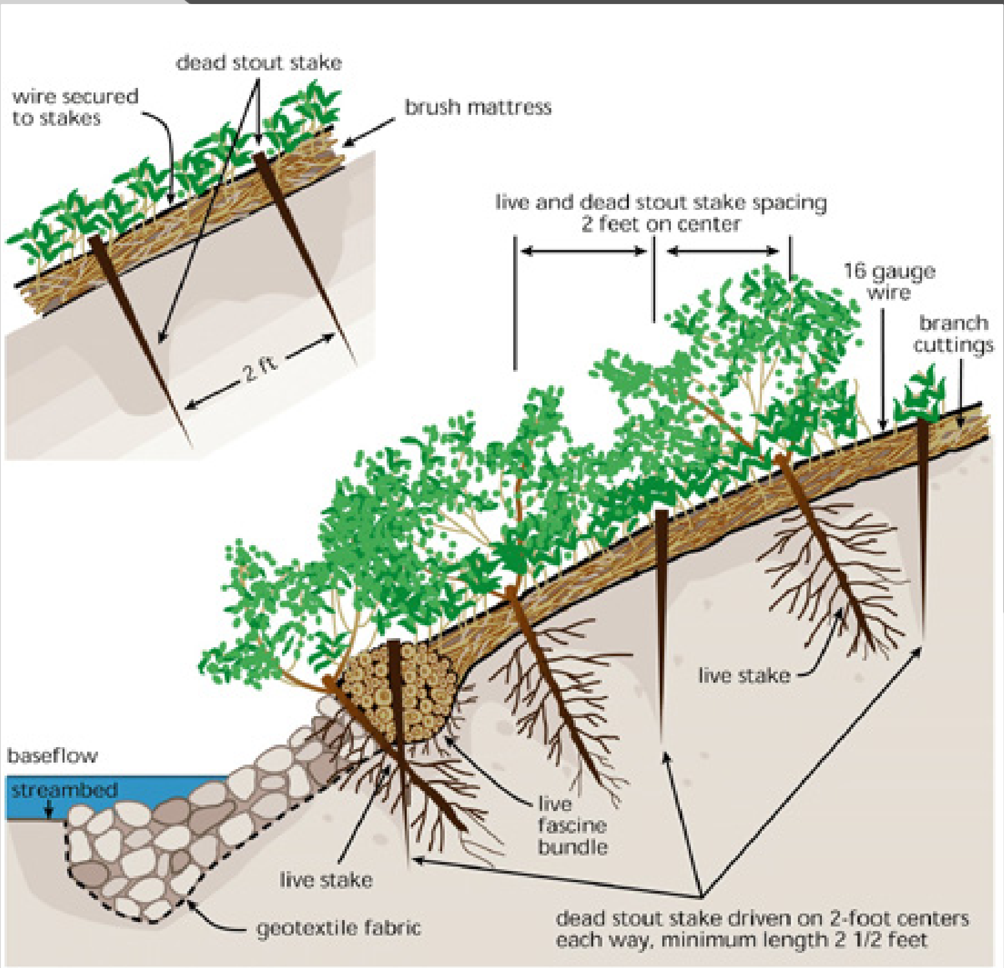


Image: Ontario's Stream Rehabilitation Manual.

Live staking



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Root wads

- Purpose
  - **Deflects current away from unstable banks**
  - **Provides complex instream cover for fish and substrate for aquatic macroinvertebrates**
- Efficacy
  - **Effective with larger erosion problems**

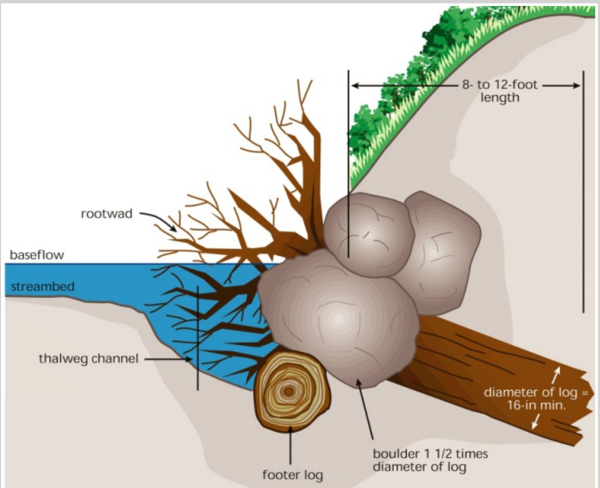


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

Altered width/depth ratio

Potential causes:

- Vegetative clearing
- Water withdrawal
- Channelization
- Streambank armoring
- Streambed disturbance
- Dams
- Levees
- Hard surfacing
- Roads and railroads
- Overgrazing
- Reduction of floodplain
- Dredging for mineral extraction
- Bridges
- Woody debris removal
- Piped discharge

Altered width/depth ratio: restoration

Wing deflectors:

Purpose

- Reduces the width to depth ratio
- Forms scour pools and increases velocity and depth providing habitat
- Single wing deflectors can direct current away from eroding banks

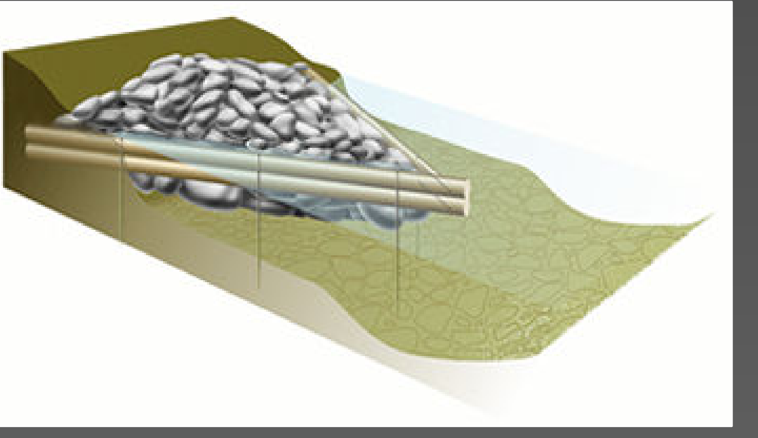


Image: Ontario's Stream Rehabilitation Manual.

Wing Deflectors

Efficacy

- Effective, but require monitoring and maintenance

Image: Ontario's Stream Rehabilitation Manual.

Potential causes of altered sinuosity

- Channelization
- Streambank armoring
- Streambed disturbance
- Dams
- Levees
- Hard surfacing
- Reduction of floodplain
- Land grading
- Woody debris removal
- Piped discharge

Potential causes of altered flow

- Vegetative Clearing
- Channelization
- Streambank armoring
- Water withdrawal
- Dams
- Levees
- Soil exposure or compaction
- Irrigation or drainage
- Hard surfacing
- Overgrazing
- Roads and railroads
- Reduction of floodplain
- Land grading
- Piped discharge

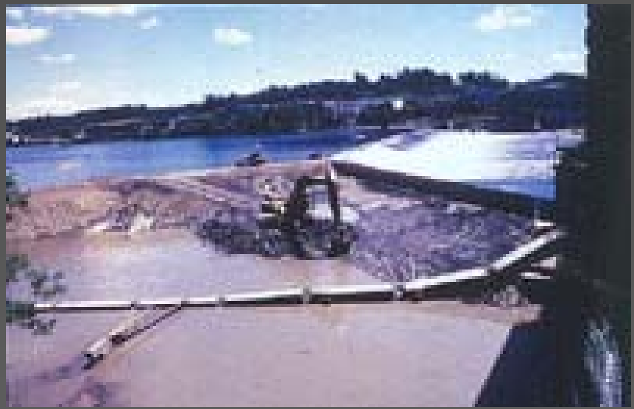
Altered Flow: Restoration

Dam Removal

- Sediment
  - Needs treatment if contaminated
  - Concentrations of nutrients in sediment probably high
- Hard to predict what will happen when dam removed
  - Stream type will evolve after dam removal

Dam removal

1. Breaching of dam



2. Temporary coffer-dams built to work behind

3. Sediment removal

4. Disposal of timbers off-site

Increased Water Temperatures and Reduced Instream Oxygen Concentrations

Potential Causes

- Vegetative Clearing
- Channelization
- Streambank armoring
- Water withdrawal
- Dams
- Levees
- Hard surfacing
- Overgrazing
- Reduction of floodplain
- Dredging for mineral extraction
- Woody debris removal
- Piped discharge

Altered Temp and DO: Restoration

Revegetation of riparian areas

Site preparation:

- Possibly re-grade bank
- Control existing exotic species

Check the soil conditions (lack of nutrients)

Tillage and mulching may increase planting success and decrease weediness

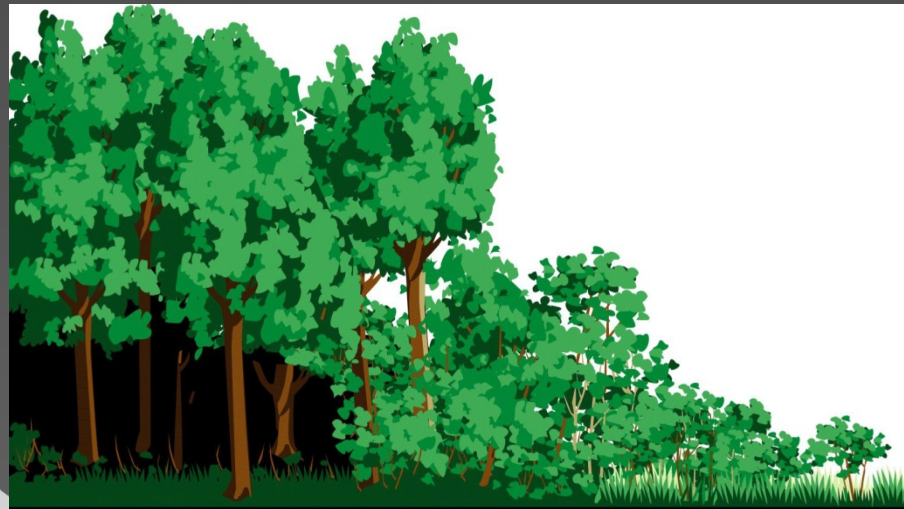
Best management practices such as fencing livestock

Revegetation

Method:

- Use a reference site
  - Determine species diversity, horizontal and vertical structure of canopy, sub-canopy, understory, and ground-layer
- Determine which plants will recolonize site naturally
  - Small existing plant populations, seed bank, nearby populations of wind and animal dispersed species a reference site

Revegetation



- Planting techniques
  - **Final density, multi-stage, dense initial, or accelerated succession**
- Works well as a community stewardship project

Revegetation

Other considerations

- Landscape connectivity to existing habitats
- Increase in woody debris could be positive
- How will nutrient cycles be impacted?

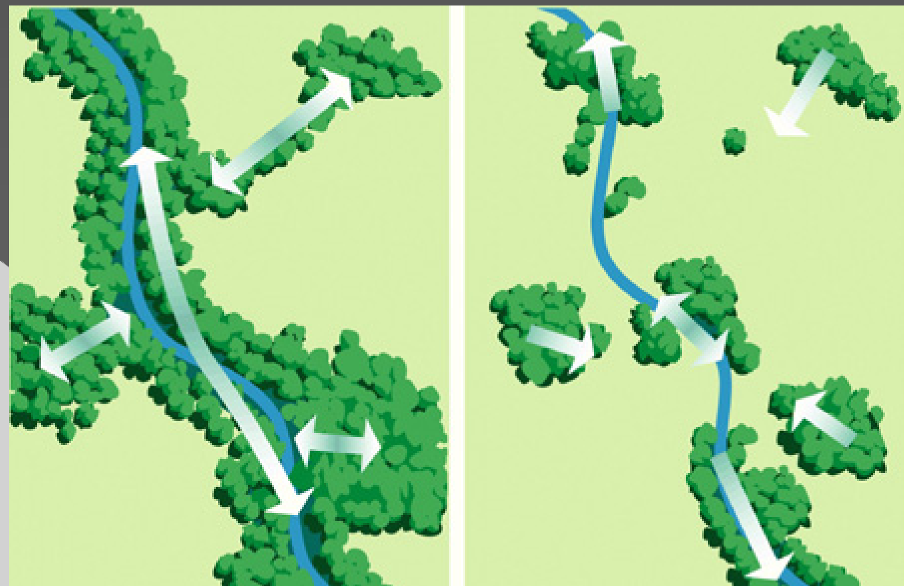


Image: Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, by FISRWG.

Revegetation

Management

- Vital to water plants
- Continue to control exotic species
- Consider impacts of herbivores

Two years after planting

basic river restoration steps

- general steps for a particular site:
  1. **assessment/diagnosis:** what needs restoring?
  2. **design:** how to accomplish this
  3. **implementation:** accomplishing it…can be pretty slow
  4. **monitoring:** is it working?

- context, context, context
  - **spatial:** what kind of stream is this?
    - braided, meandering? cascade, step-pool, pool riffle?
  - **temporal:** what was the disturbance history?
    - dam? logging? channel management? **when?**

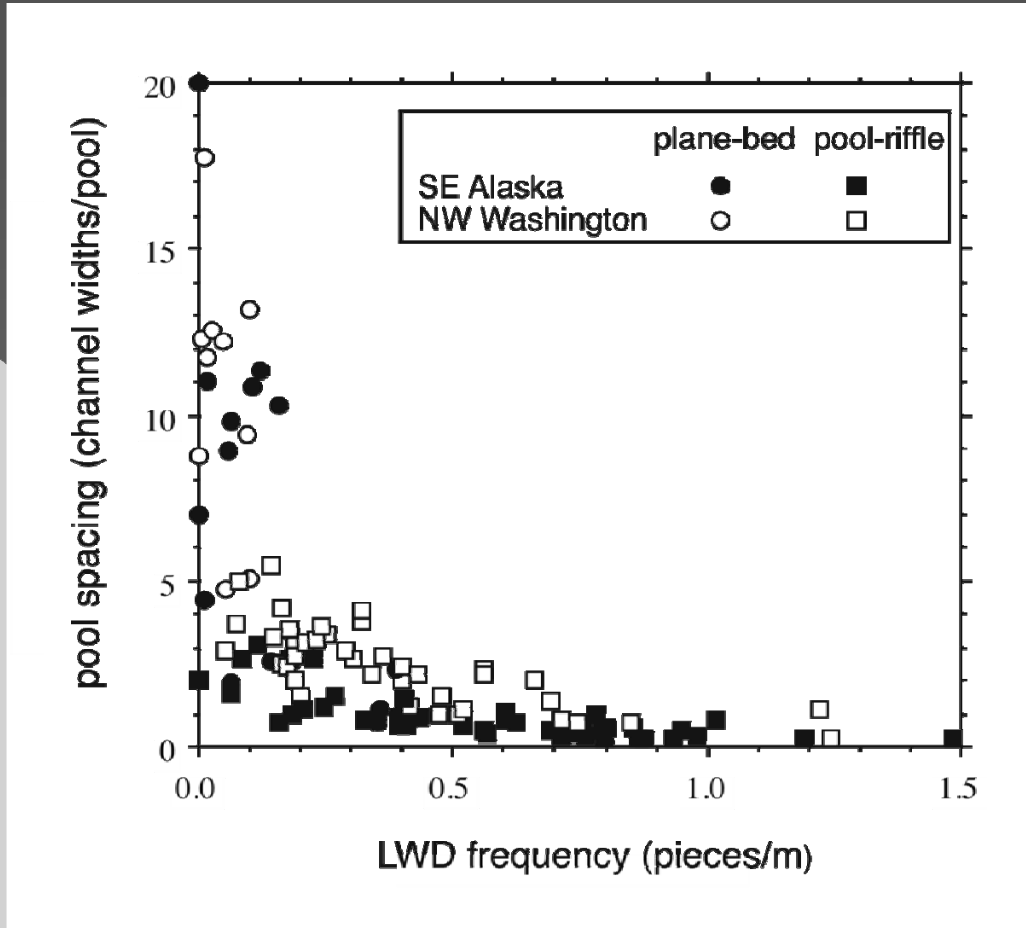
restoration of LWD

- **LWD:** large wood(y) debris
- wood acts as an impediment to flow:
  - can cause flow convergence and scour pools that provide important

&

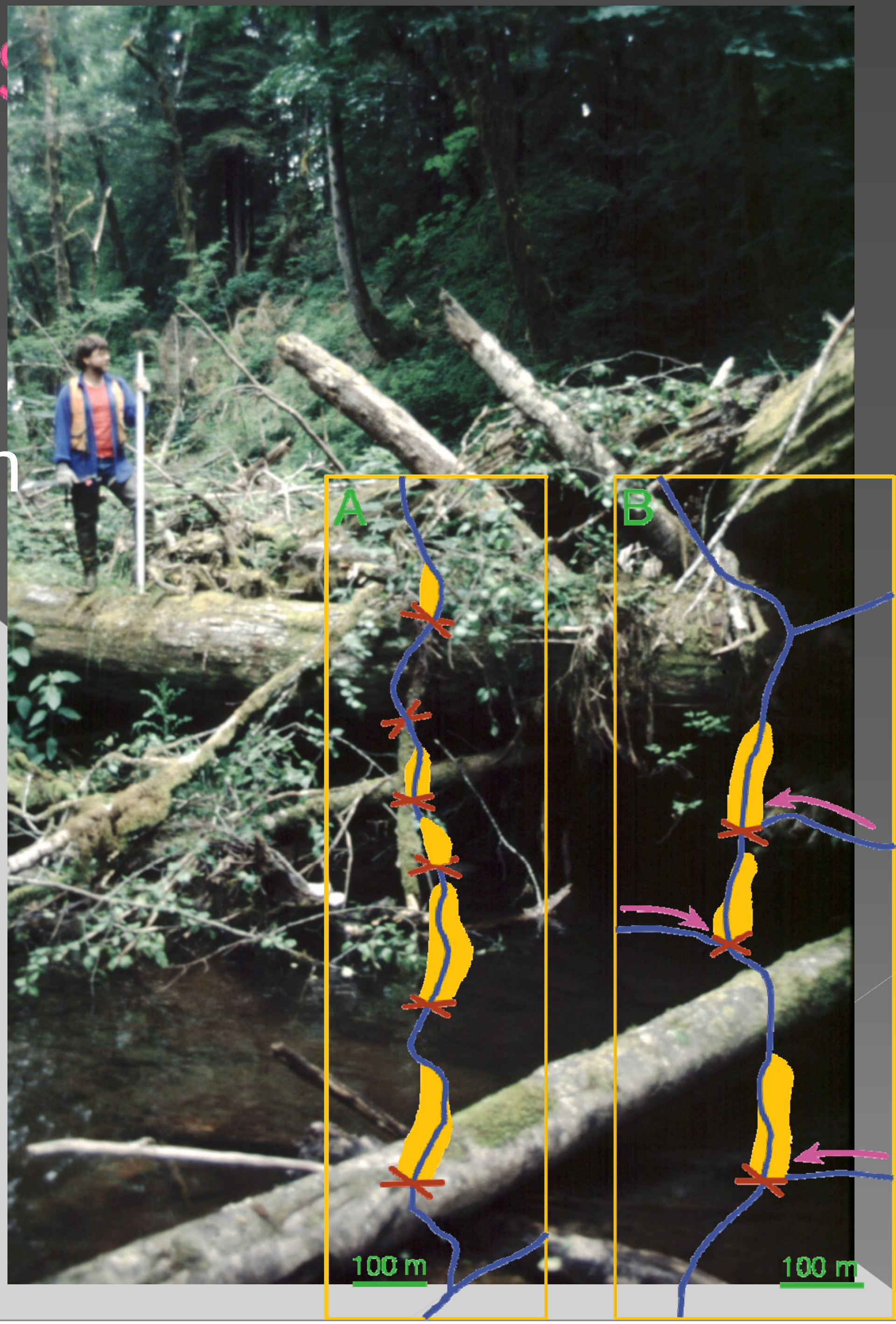
LWD at pool-riffle scale

- more wood → more pools
- For channels surveyed in chanel:
  - plane-bed morphology occurs only at low LWD loading
- LWD can control the formation of pools and bars, and thereby channel reach morphology

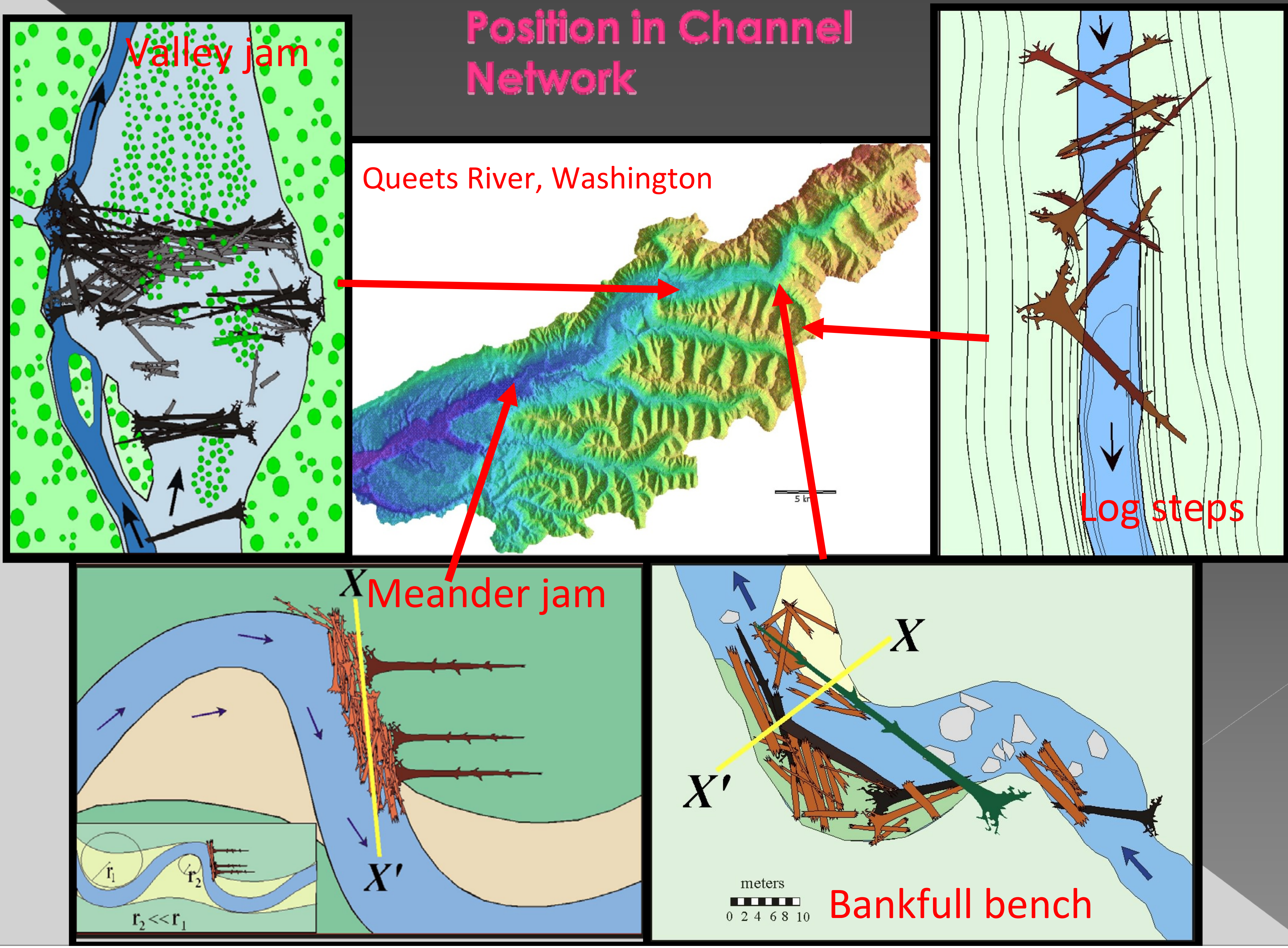


LWD @ valley s

- Log jams trap large amounts of sediment and can lead to aggradation along entire channel reaches
- Both locally recruited trees and log jams delivered by debris flows can create alluvial valley bottoms in confined mountain streams.



Position in Channel Network



LWD restoration

- restoration of natural wood loading would take centuries:
  - large key members take a long time to grow

so:

reintroduction of large woody debris

Basic steps to a restoration project – most of these steps require an interdisciplinary approach

- Problem identification – what is wrong? Is it actually a problem?
- Societal context –stakeholders interests, funding sources, regulations, cultural issues, etc.
- Define achievable goals - be specific
- Assess site at watershed-level (best to act at watershed level if possible, or at least understand constraints on system), and at the reach-level, including longitudinal and lateral connectivity
- Identify alternatives, evaluate, and choose design
- Implementation – including construction monitoring
- Monitoring and assessment; Adaptive management

Goals of this course/program

- Balance basic fundamentals of fluvial geomorphology, hydrology, and ecology with practical information
- "EMT" level of understanding for restoring damaged streams
- Focus on ability to evaluate and critique restoration project (learn from past failures and successes)
- Tools to design relatively simple restoration projects on small streams
- Turn you into effective team members on restoration projects
- Give you the tools to do both a watershed-scale assessment and a reach-scale analysis of a potential site and make you think about a river over multiple temporal and spatial scales.

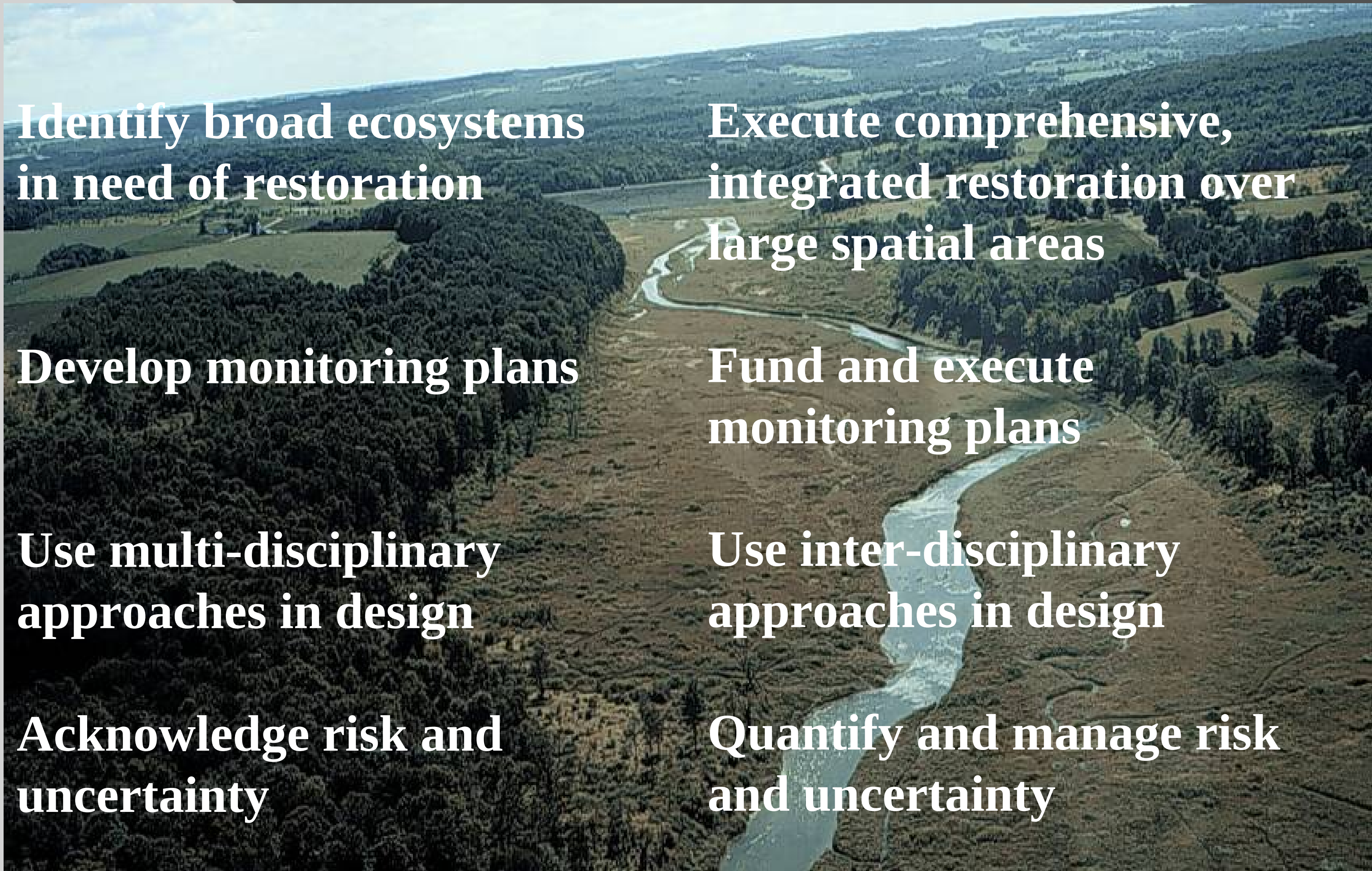
This program will NOT teach you…

- How to design large-scale restoration projects: this requires a team of subject-area experts and years of experience
- How to work in highly urbanized settings, where life and property are at risk
- Rosgen's toolbox for natural channel design: There are numerous short courses to learn this tool…

We Can:	We Can't (or Won't):
Stabilize channels and banks	Allow for a full range of dynamic processes
Identify project objectives	Relate these to meaningful standards or metrics
Design systems that mimic reference conditions	Ensure that they are appropriate or functional
Characterize ANY action as restoration	Fully restore both the form and function of most systems to pre-disturbance

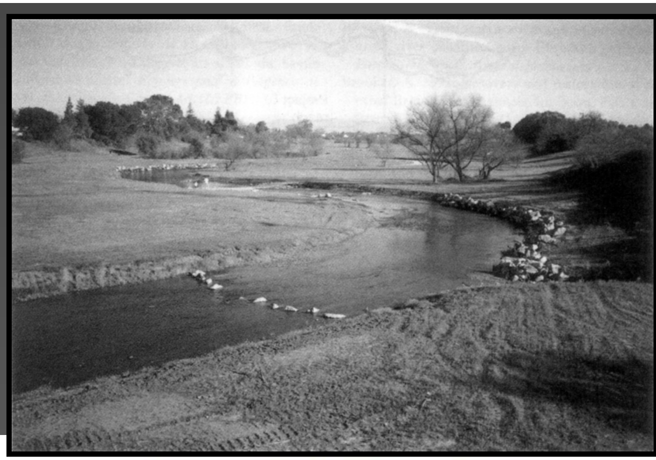
We Can:

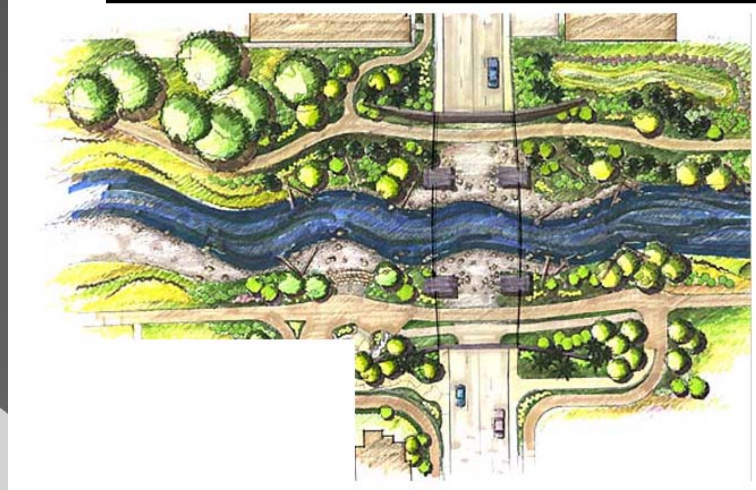
We Can't (or Won't):



We Can:	We Can't (or Won't):
Identify broad ecosystems in need of restoration	Execute comprehensive, integrated restoration over large spatial areas
Develop monitoring plans	Fund and execute monitoring plans
Use multi-disciplinary approaches in design	Use inter-disciplinary approaches in design
Acknowledge risk and uncertainty	Quantify and manage risk and uncertainty

- 10 commandments of river restoration (according to Dave):
  1. do no harm
  2. look beyond the channel to assess it in its context
  3. use native materials
  4. emulate natural analogs
  5. let channels do the work
  6. let the channel use its floodplain
  7. manage inputs to the system so that the river can fix itself
  8. use direct manipulation of the channel as a last resort
  9. allow for the river to make its own changes
  10. use qualified/appropriate personnel to design restoration efforts





Overall Words of Advice for the River Restorer: FIRST, DO NO HARM!

"There is renewed emphasis on recovering damaged rivers (Baringa 1996). Along with this concern, however, people should be reminded periodically that they serve as stewards of watersheds, not just tinkerers with stream sites. Streams in pristine condition, for example, should not be artificially "improved" by active rehabilitation methods.

At the other end of the spectrum, and particularly where degradation is caused by off-stream activities, the best solution to a river management problem might be to remove the problem sources and "let it heal itself". Unfortunately, in severely degraded streams, this process can take a long time. Therefore the "leave it alone" concept can be the most difficult approach for people to accept (Gordon et al. 1992)."

From FISRG, 1998, Stream Corridor Restoration, p. 8-2.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